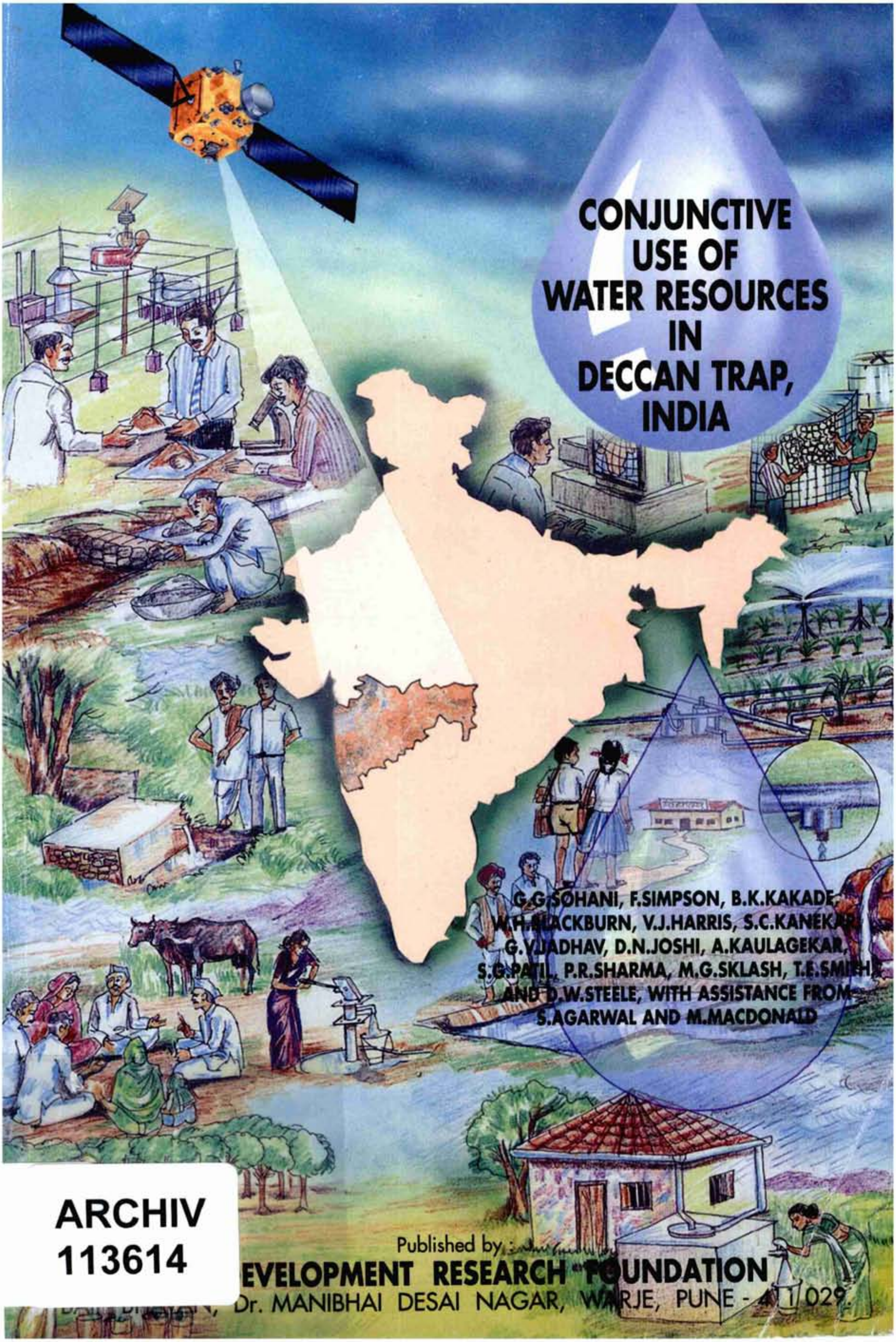


CONJUNCTIVE USE OF WATER RESOURCES IN DECCAN TRAP, INDIA

G.G.SOHANI, F.SIMPSON, B.K.KAKADE, W.H.BLACKBURN, V.J.HARRIS, S.C.KANEKAR, G.V.JADHAV, D.N.JOSHI, A.KAULAGEKAR, S.G.PATIL, P.R.SHARMA, M.G.SKLASH, T.E.SMITH AND D.W.STEELE, WITH ASSISTANCE FROM S.AGARWAL AND M.MACDONALD

Published by :
EVELOPMENT RESEARCH FOUNDATION
Dr. MANIBHAI DESAI NAGAR, WARJE, PUNE - 411 029.

CONJUNCTIVE USE OF WATER RESOURCES IN DECCAN TRAP, INDIA

RESEARCH REPORT
1998

by

G. G. SOHANI, F. SIMPSON, B. K. KAKADE,
W. H. BLACKBURN, V. J. HARRIS,
G. V. JADHAV, D. N. JOSHI, S. C. KANEKAR,
A. KAULAGEKAR, S. G. PATIL, P. R. SHARMA,
M. G. SKLASH, T. E. SMITH, AND D. W. STEELE,
WITH ASSISTANCE FROM S. AGARWAL AND
M. MACDONALD

BAIF Development Research Foundation
Dr. Manibhai Desai Nagar,
National Highway No. 4, Warje,
Pune 411 029, India

University of Windsor
Earth Sciences
401 Sunset Avenue, Windsor, Ontario
Canada N9B 3P4

This work was carried out with the aid of a
grant from the International Development
Research Centre, Ottawa, Canada
(IDRC Grant No. : 91-1018-02)

It is recommended that reference to the whole or to part of
this report be made in the following form :
Sohani, G.G., Simpson, F., *et al.*, 1998.
Conjuctive Use of Water Resourses in Deccan Trap, India.
Pune, BAIF Development Research Foundation.-134 PP.

Price : Rs. 200/-

Published by :

BAIF DEVELOPMENT RESEARCH FOUNDATION,
DR. MANIBHAI DESAI NAGAR, NATIONAL HIGHWAY NO. 4,
WARJE, PUNE - 411 029, INDIA

ISBN : 81-87511-00-1
Cover Design : Artwork by **Ashish Advertising, Pune,** based on an idea by **B.K. Kakade;**
Printed by : **Ashish Advertising, Pune**
Copies of this publication may be obtained from the publishers.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the guidance of Manibhai Desai, the late founder and first President of BAIF. Kind support and encouragement from his successor, Narayan Hegde, is greatly appreciated.

The following BAIF field officers in Akole Taluka contributed substantially toward the success of the project through their daily interaction with the tribal and rural people : M.M. Shaikh, R.M. Dabhade, R.S. Tajne, B.K. Patil, V.V. Gore, J.V.Koyte, B.B. Bhosle, S.S. Kulkarni and P.R. Kshirsagar.

The following BAIF personnel were responsible for the needs assessment, presented in this report in a somewhat amended form : I.P. Bhagwat, V. Gadgil, A. Ghorpade and N. H. Gole.

Among the tribal and rural people of Akole Taluka, many organized groups, families and individuals in Ambevangan, Manhere and Titvi contributed to the success of the project. In particular, the help of the following individuals was greatly appreciated : Ramdas Bahirse Dhande, Tukaram Puna Gabhale, Tukaram Bhorre Gabhale, Kalavati Tukaram Gabhale, Shantabai Kalu Dhongade, Sakharam Bhau Mundhe, Ganpat Bhiva Dhande and Raghunat Rama Dhande.

The Space Application Centre, Ahmedabad, colloborated with BAIF on the mapping of lineaments from satellite imagery and provided a number of base maps, used in the early stages of the project. The Maharashtra Remote Sensing Application Centre, Nagpur, made available a number of additional base maps. Indian Meteorological Department provided all the meteorological information required for the project.

At the University of Windsor, help and encouragement were given at the start of the project by E.D. Briggs, of the Institute of International and Development Studies, and later by R.J. Cattaneo, of the Office of International Affairs.

The project was made possible by funding from the International Development Research Centre, Ottawa. Aung Gyi (Singapore and New Delhi) and J.P. Hea (Ottawa) provided advice and helpful discussion, especially at the beginning of the joint activities. S. Dufour (Nairobi and Ottawa) and L. Chretien (Ottawa) kindly gave valuable assistance in different stages of the project. N.I. Faruqui (Ottawa) played an important part in the early dissemination of project results.

The methodology, learning and intervention ideas generated during implementation of the project in pilot areas of the three project villages immediately were replicated in other areas of these and adjoining villages through support received from NABARD under the Indo-German Watershed Programme. This support made possible treatment of the entensive watershed area which directly resulted in a substantial improvement in the water regime and augmented the project outcomes.

The authors gratefully acknowledge their indebtedness to all of these individuals and organizations.

FOREWORD

Water is the lifeline for all human activities and development programmes. Even after 50 years of independence, over 50% of our villagers do not have adequate potable water and about 80% of water consumed on rural areas is unfit as per World Health Organisation (WHO) standards. In an agrarian country like India water is the foundation for all income generation activities particularly in rural areas. Hence, water resource management should be the primary focus of development in India.

Although there are many sources of water, we are primarily dependent on rainfall. If we can ensure optimum use of rain water, agriculture growth can surpass the industrial development. Unfortunately, only 25% of the water is effectively utilised in the country. With the changing environment and ecological degradation, more and more rain water runs off, taking away fertile agricultural soils, causing floods and siltation of water reservoirs and rivers. In the absence of proper water resource management, it will be difficult even to optimally use other natural resources such as land, vegetation and livestock which are considered to be the mainstay of our economy. Hence water resource management, particularly conservation of the rain water for optimal use, calls for the attention of planners and farmers.

Water scarcity and related problems are not only related to drought prone areas, but also affect heavy rainfall areas. Most of our Western Ghats suffer from this syndrome. Akole taluka in Ahmednagar district in Maharashtra where BAIF has been involved in rehabilitation of tribal families, posed a similar challenge. The area receives about 1500 mm of rainfall spread over four months and the farmers suffer from the acute shortage of drinking water for three to four months in a year. To address this problem of water scarcity, BAIF approached the International Development Research Centre (IDRC), Canada to support this research project. The University of Windsor, Canada, associated with us for providing technical support.

Under this project, geohydrological systems were studied and traditional sources of water were also examined. Various water saving and tapping systems were introduced in the project villages. The project demonstrated the effective use of rain water for improved agricultural production while maintaining a clean environment. In the absence of perennial sources even a single cropping system making use of rain water can provide a substantial rise in yield and income.

The project also highlighted the role of soil conservation measures in preventing soil erosion, thereby improving productivity of soils. The project developed a methodology for systematic water resources management by establishing a rationale for water resource management, evaluation of water potential, classification of land capabilities, and village water use and upgradation in technical knowledge of BAIF staff and improved technical skills of the villagers.

We are convinced that the strategy should have multidisciplinary approach for ensuring people's participation, formation of women's groups, operations of grain banks, stores, micro-credit and small scale enterprises which play very significant role in sustaining the interest of the participants. However, the gestation period is slightly long and the benefits start accruing after two to three years. During, this initial period, it is extremely important to sustain the interest of the community and to harness maximum benefits of the project, select suitable cropping system, promote wind breaks with horticulture and new crops and develop local structure to ensure smooth inflow of technical information and agricultural inputs. Post production activities can also play a very significant role.

This project has made a modest beginning in this direction. We are grateful to the Department of Earth Sciences, University of Windsor for being a partner and providing technical guidance and to the International Development Research Centre for providing financial support to implement this project. I take this opportunity to compliment the scientists of BAIF, University of Windsor and IDRC who have worked together to complete this project successfully. We are also grateful to our participant families, who had great faith in BAIF's project implementation team and the new experiments and technological innovations introduced to them.

Through this publication, we have made an attempt to share our experience with the scientists and field officers involved in watershed development in the tropics. We hope this document will help in easy replication of various appropriate technologies, boost water resource management and development in the country.

Dr. Narayan Hegde
President, BAIF

PREFACE

This report summarizes the research results, arising from the project, "*Conjunctive Use of Water Resources in Deccan Trap, India*". The project was carried out by BAIF Development Research Foundation, Pune, India, and the Department of Earth Sciences, University of Windsor, Ontario, Canada, working in partnership with the tribal and rural people of Akole Taluka, Ahmednagar District, Maharashtra.

The collaboration was made possible by funding from the International Development Research Centre, Ottawa, Canada. The project term of three years began in April, 1992, and was later extended by one year. Unspent funds, administered by the Canadian project team, allowed the Canadian project leader to visit India in April-May, 1997, more than a year after the end of the project. This visit permitted discussions of project sustainability and the planning of how research results would be disseminated.

The purpose of the project was to design a strategy of water-resource management that would provide three villages in Akole Taluka with a year-round supply. The approach taken was to integrate indigenous knowledge with different levels of technology, including millenia-old techniques, transferred from other dryland regions. Alternative approaches to water-resource management were tested by means of pilot projects.

The project was successful. Water from the 1996 monsoon was still available for use by the tribal and rural people of all three villages in late May of 1997. Other beneficial changes in the area were clearly evident. There were improvements in the availability of food, the health of villagers, their material standard of living, and the morale of the people. As well, the success of the project prompted a spate of similar activities in the surrounding area. This dry part of Ahmednagar District was about to be transformed for ever!

Of course, life is still hard in Akole Taluka. It is likely to remain so for years to come. Furthermore, the tribal and rural people must continue to cope with changes to their lives, brought about by increased availability of water. In the pages that follow, the strategy for improved management of water resources in the area is outlined. As well, attention is paid to the additional benefits, gained by the villagers, as a result of easier access to water.

Girish G. Sohani
Indian Project Leader

Frank Simpson
Canadian Project Leader

CONTENTS

PAGE NO.

PAGE NO.

LIST OF ANNEXURES

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Conjunctive Use of Water Resources in Deccan Trap, India, was a multidisciplinary research project, involving BAIF Development Research Foundation, Pune, India and the Department of Earth Sciences, University of Windsor, Ontario, Canada, in the partnership with the tribal and rural people of Akole Taluka, Maharashtra. The four-year collaboration was made possible by the International Development Research Centre, Ottawa, Canada, which facilitated the initial contacts and provided financial support.

An inital needs assessment took the form of a participatory rural appraisal that included a survey of water use and a health evaluation. It also identified the villagers of Ambevangan, Manhere and Titvi as the local collaborators. The project goal was to improve management of water resources, by the tribal and rural people. The project purpose was to develop a methodology for the sustainable, year-round utilization of surface water and ground water.

Outputs of the project, leading to achievement of both the purpose and the goal, include :

1) a rationale for systematic development of available water resources by means of socially and economically acceptable procedures;
2) an evaluation of water-resource potential through integrated geological, hydrogeological and hydrological study of selected areas;
3) a land capability classification, incorporating data on slope characteristics, soil properties and agricultural potential;
4) an analysis of village water use and needs, combined with relevant, methodological data;
5) trained BAIF personnel with upgraded research capability in technologies of water-resource management; and
6) trained villagers, able to initiate water-harvesting and-spreading methods and related approaches to soil conservation.

Project inputs, giving rise to these outputs, included training, laboratory and field programmes, computer software and equipment, promotion of the project, and design and implementation of demonstration sites for water-resource development.

Technological applications in the project were diverse in nature and origin, as well as in level. The indigenous knowledge of villagers, especially concerning biological indicators of shallow ground water and the relationship of terrain to ground-water discharge, was an important starting point. Some of the catchment area modifications employed are related to techniques, used by the Nabotean culture and its predecessors in the Negev Desert four thousand years ago. In contrast, high-technology applications included imagery and location data from Earth satellites in geographic information systems for the computerised generation of maps and precise location in the field by means of a global positioning system; chemical analyses of rock samples and chemical and isotopic analyses of water samples in the laboratory; and measurement of electrical conductivity of water, hydraulic conductivity of soil, and the magnitude of radon emissions in the field. The information obtained in these very different ways was integrated to give intermediate-technology solutions to problems in water-resource management. It was important that these solutions could be understood and put into effect by the tribal and rural people.

The water-resource management strategy developed employs demonstration sites that display a wide range of intermediate-technology approaches to water conservation and utilization. To a large extent, it builds upon the indigenous knowledge of the tribal and rural people of Akole Taluka :

1) Techniques, referable maily to the surface circuit of the hydrologic cycle, use barriers (contour bunds, *nalla* bunds, check-dams, gabions) and shallow excavations (contour trenches, farm ponds, bedrock excavations), as well as natural and artificial surfaces. They complement the soil-conservation function of the terraces on hill slopes under agricultural cultivation, exploit the short-lived, channelized flow of ephemeral streams, and also take water from road surfaces and roofs of dwellings.

2) The subsurface circuit is harnessed by means of shallow excavations to enhance recharge (recharge pits and trenches) and , at other locations, to contain discharge of ground water, (spring development) and through improvements to existing dug wells and bore wells for aquifer development. Simple tanks and other structures have been installed for development of springs and seepages. Underground dams were also employed.

Alternative techniques for the extraction of water from the atmosphere as evaporation waters (modified Mexican still, solar still) and dew ponds were presented for possible survival use by separate families and individuals, under conditions of extreme water shortage.

Long-term benefits to villagers, arising out of adoption of the management strategy, were observed over a year after termination of the project. These include :

1) the year-round availability of water at some check-dams, gravity-flow systems, developed springs, and dug wells;

2) a reduction in the traditional, water-related hardships, experienced by village women and children;

3) a reduction in the incidence of skin diseases and other health problems, connected with water shortages;

4) personal motivation of villagers to improve water quality, combined with a new interest in hygiene;

5) a contribution to improved, agricultural production and material gains from the sale of produce;

6) an increase in employment opportunities in the villages and reduced pressure on men to work a way from home;

7) improved employment prospects, related to vocational training, for villagers, who elect to work away from home;

8) the planning by villagers of expanded use for excess water, such as in irrigation schemes;

9) the planning of new, agricultural enterprises by individuals and village cooperatives;

10) improved livestock quality, with concomitant reduction in livestock numbers, as more land is used in agriculture; and

11) improved morale of villagers. evidenced by more outgoing attitudes, better upkeep of houses, etc.

Many of these beneficial effects have evolved gradually during the collaborative project. The inventory of benefits to villagers will provide a basis for establishment of sustainability indicators in the planning of similar, future projects.

Key concepts : conjunctive use of water resources, needs assessment, indigenous knowledge, intermediate-technology solutions, sustainability indicators.

◆◆◆◆

1: INTRODUCTION

1.1 STATEMENT OF PROBLEM

The Deccan Trap basalts cover an area of about 500,000 sq km in Central India. They are spread over the states of Maharashtra, Madhya Pradesh, Gujarat and Karnataka. The Deccan Trap encompasses different agroclimatic zones. These zones differ from each other in type of soil cover and its extent, total precipitation, percolation, evapo-transpiration and vegetation. Basaltic rocks are hard and compact and do not possess significant primary porosity. However, secondary porosity is present as a result of weathering, jointing and fracturing. Groundwater occurs in these rocks in the secondary porosity of the weathered bedrock. The joints and fissures act as conduits for groundwater. The capacity of the rocks to hold and transmit water is limited and is largely controlled by the intensity of weathering and extent of joints and fractures.

The Deccan Trap area has wide rainfall variations, ranging from severe floods in Western Maharashtra in the rainy season to frequent drought conditions in some districts of Central Maharashtra. A large area suffers, due to deficiency of soil moisture and high potential evaporation rates. In many areas a large number of aquifers are inadequately saturated, due to geomorphological characters and poor permeability of the strata. As a consequence, borewells and dugwells are of the poor-yielding category.

The physiographic conditions in the Deccan Trap terrain are also very uneven with steep slopes in some places. The rugged topography contributes to the large run-off from the streams. These conditions of rainfall uncertainties and hillslopes lead to inadequate water, both for irrigation and drinking purposes. The conservation and utilisation of water resources are, therefore, crucial in meeting the irrigation and drinking water demands of the rural population. This assumes even greater significance during conditions of scarcity.

It was against this background that a project was conceived for developing a methodology for conjunctive use of surface water and ground water in the Deccan Trap.

1.2 BACKGROUND INFORMATION

BAIF Development Research Foundation, a non-government voluntary organisation, initiated its Integrated Tribal Rehabilitation Programme six years ago in Akole Taluka of Ahmednagar District. The programme includes horticulture, forestry, wasteland development and water resources development. An integrated watershed development project also was added since 1993.

The area is typical of the Western Ghats part of the Deccan Trap. It receives heavy rainfall during the monsoon and faces acute water scarcity in summer. BAIF identified a need for developing appropriate methodology to make maximum use of available water sources and to alleviate the scarcity problem to the maximum extent possible. Accordingly, a project with the sponsorship of IDRC was launched in April, 1992, to develop a systematic approach for optimum utilisation of surface as well as ground water resources.

The project was undertaken jointly by BAIF Development Research Foundation, Pune, India, and the Department of Earth Sciences (formerly the Department of Geology), University of Windsor, Canada.

1.2.1 PROJECT AREA

A. Location

The project was initiated in three micro-watersheds of three villages, namely Manhere, Ambevangan and Titvi in Akole Taluka of Ahmednagar District, Maharashtra, India. The project area is situated between longitudes 73°45' East and 73°55' East and latitudes 19°30' North and 19°40' North. The area lies in the Deccan Trap region and forms part of Western Ghats mountain range. It is situated in the western part of Ahmednagar District, bordering Nashik District. Nashik, at a distance of 85 km, is the nearest city to the project area. **Figure 1.1** provides a map of the project area.

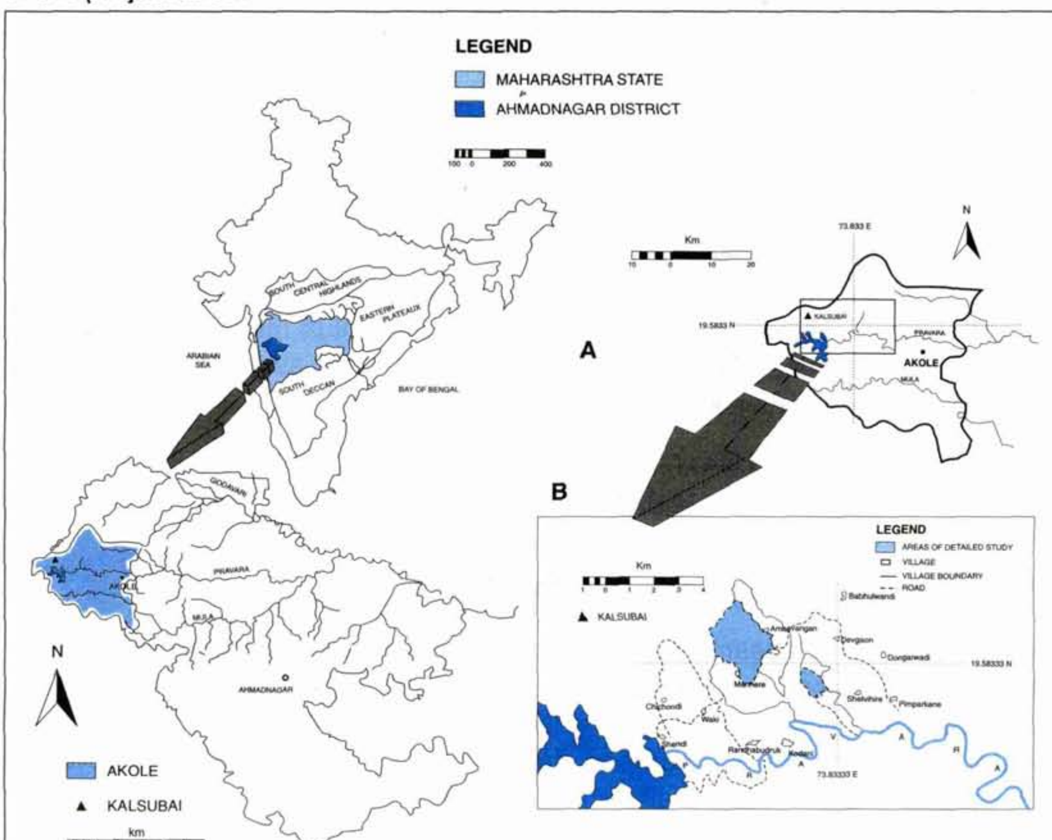


FIG. 1.1 PROJECT AREA

B. Topography and Drainage

The area is characterised by a rugged range of hills, forming the highest part of the Western Ghats. Kalsubai, the highest peak of the Western Ghats mountain range is only about 5 km away from the project area. The hills in the north of the project area near the villages of Manhere and Ambevangan are at an elevation of over 1000 meters above mean sea level. The general slope of the area is towards the south.

The area is part of the Godavari River drainage basin, with the Pravara River as the main drainage channel. The project area is well drained by numerous streams and their tributaries, which originate in the hills to the north, finally joining the Pravara to the south of the project area.

C. Rainfall and Climate

The project area lies in the tropical zone and receives all of its annual precipitation from the Southwest Monsoon. The rainy season normally starts in mid-June and ends by the beginning of October. July is the wettest month of the year, followed by August. There is a very high variation in the rainfall within the region, from about 2000 mm in the far west of the project area to 600 mm in the eastern part.

D. Geology and Groundwater

The area is covered by Deccan Trap basaltic rocks; amygdaloidal basalts form the bedrock. There is shallow soil cover, overlying weathered and fractured rocks, resting on hard massive basalt. The basalts are nearly horizontal, separated by thin layers of ancient soil and volcanic ash (red bole). Numerous fractures, mainly trending northwestwards, exist in the area.

Groundwater occurs mainly in the superficial deposits, the weathered basalt and the fractured and jointed basalt. The principal water-bearing zones are shallow aquifers in the soil and weathered bedrock ranging from 3 to 5 m below the ground. **Annexure 1** gives a well inventory of the area.

1.3 PROJECT OBJECTIVES

1.3.1 GENERAL OBJECTIVES

The overall objective of this collaborative project was to develop a methodology for the sustainable exploitation and utilisation of surface and groundwater resources through integration of geological, hydrogeological, and hydrological studies with the participation of the tribal and rural communities in the Deccan Trap area.

1.3.2 SPECIFIC OBJECTIVES

1. To collect essential baseline data.
2. To carry out geological, hydrological and hydrogeological studies of specific watershed areas with a view to locating and identifying the available resources.

3. To develop socially and economically acceptable methods for the exploitation and utilisation of available water resources.

1.4 SCOPE AND METHODOLOGY OF WORK

Secondary data of relevant parameters were collected from all possible sources with a view to understanding the area, the people and their priority needs. This was the first step before initiating actual experiments.

1.4.1 SCOPE

Three micro-watersheds were selected in three villages namely Manhere, Titvi and Ambevangan with an area of 300 ha., 81.79 ha. and 205 ha. respectively. These watersheds were studied thoroughly with regards to climate, topography and geohydrology. The major thrust was to study the relevance of all the factors to the development of a methodology for conjunctive use of water resources in the study area.

1.4.2 METHODOLOGY

The work was divided into three phases as given below :

Phase I : Data Collection

- Collection of socio-economic baseline data.
- Establishment of meteorological stations and collection of meteorological data
- Preparation of topographic and land capability maps
- Collection of remote sensing data
- Analysis of data

Phase II : Field and Laboratory Studies

- Geological studies
- Study of bedrock
- Study of lineaments
- Study of ground features having geological significance.
- Hydrological studies
- Application of relevant experimental measures

Phase III : Standardisation of Research Results

- Analysis and study of the data and experiments
- Standardisation of designs for experimental measures
- Study of the utility of the ground features
- Impact analysis

◆◆◆◆

2: NEEDS ASSESSMENT

2.1 RAPID APPRAISAL OF DRINKING WATER ACCESS AND USE

2.1.1 INTRODUCTION

As a step toward developing a permanent solution to the drinking-water problem in Akole Taluka, a rapid appraisal of the drinking-water problem in this area was taken up in 1990 by a team of specialists from various fields.

2.1.2 METHODOLOGY

The methodology used for rapid appraisal of drinking water access and use is as given below :

- **Interview schedule.** A schedule and format prepared helped in pre-survey dialogue and data-collection.
- **Survey team.** Specialists from the fields of health, engineering, agriculture, management, enabled a multi-dimensional analysis.
- **Mode of data collection.** Dialogue, discussions with the local people, home visits and visits to the water sources yielded various observations.
- **Duration.** Three weeks. Visits covered the summer and monsoon season and information of the rest of the year was obtained through discussions.
- **Secondary data collection.** Meteorological observatory, hydrogeologists, contour maps and other literature were utilized.

2.1.3 RESULTS

The results of the rapid appraisal are given below :

A. General

The villages located on hilltops, are small and the populations are sparse between 200-1100 people in each village. A scheduled tribe, the Mahadeo Koli, makes up the majority of the population. The rainfall rapidly escapes as runoff and the groundwater moves quickly through weathered, fractured and jointed rocks. Shallow water-bearing zones can be found 15 to 20 ft. below ground level.

B. Water Sources

There is an acute shortage of water for 6 months of the year. The principal sources of drinking water are :

- **Dug wells.** On average each village has 2 community and 6 private wells. They are shallow (average depth 20-30 ft.) and are at a distance about 500m from dwellings. They are shallow, have no parapets and have a lining of stone/cement. Barring a few exceptions, the water is hardly used for irrigation; but is utilized for all domestic and animal chores, performed around the well itself.

- **Hand pumps.** After a survey and test drilling, the Zilla Parishad (ZP, a government body at the District level) installed India Mark II Handpumps in every village. Their apron design is acceptable, but they do not have an adequate drainage system. All of them, except two, have dried up or been damaged. There is no technical knowledge or person around to handle the problems of handpumps.
- **Mountain streams.** There are several mountain streams with flows up to January-February. These *nallas* are used by everyone for all purposes.
- **Natural springs.** The groundwater discharges at the surface in a few places. These are distant from the villages, but perennial.
- **Rivers.** The Pravara River is perennial, but owing to the distance to the villages, it is used only as a last resort.
- **Piped water.** ZP has lifted water from the Pravara River and provided it to the three villages. However, the scheme is closed, due to problems between the ZP and the village panchayat.
- **Sanitation at the water sources.** The water in the wells was filthy. All the available water sources except the pumps, are vulnerable to contamination and the pumps are not working. The Primary Health Centre (PHC) doctor said that chlorination was being done regularly, but Ortho-Tolnidine Test (OTT) tests for residual chlorine (at two village wells) gave contrary results and were reinforced by the villagers' comments.

C. Storage of Water

Water is collected and stored in brass/alluminium vessels and buckets and kept at accessible heights. A tumbler/glass is used to draw water. Water, when turbid, is filtered through a cloth. The principle of sedimentation is not known or used. Use of potassium permanganate is known, but not practiced.

D. Gastro-intestinal Morbidity

A variety of GIT disorders are observed. Diarhoeal disorders are the commonest complaints. A cholera epidemic was reported from some nearby villages in June-July 1990.

E. Water Availability in Summer

In summer, the seasonal sources dry up and there is extreme scarcity of water. Great distances have to be walked to get a limited quantity of water. Some families even have to purchase water.

Health and hygiene suffer greatly. Skin infections and diarrhoea are common. This all definitely results in amplified, economic and social problems.

Summer : Rush to fetch water after Zilla Parishad water tanker emptyed into well

F. The Attitude of the People

People look skeptically and cynically at efforts to alleviate water problems, possibly because they have become resigned to their lot.

First, seasonal water sources dry up and then people turn to other sources. Women are helped by men, but only in summer. *Harijans* (Scheduled Castes) are made to use separate wells. Piped water is already given up as a lost cause and the panchayats with few exceptions are reluctant to make available water supply by tanker truck due to the amount of paper work involved. Individual well owners want economic benefits, if others are to use their water.

A few elders blamed the water scarcity on the loss of forest cover. Wells are worshipped, but superstition has led to the closure of two wells.

2.1.4 CONCLUSIONS AND RECOMMENDATIONS

Awareness, regarding the quality and amount of drinking water, is essential. Below are the conclusions and recommendations.

A. Water-Resource Development

Though ground-water resources are very scarce, comprehensive surveys might help. Secondly, hand pumps can be repaired and reused. Advanced designs of hand pumps (India Mark III) can be installed and local families trained for their future maintenance. The next best alternative to deep bore wells are those shallow aquifers. In the case of existing wells, deepening, artificial fracturing, covering, constructing aprons and installing hand pumps can be done. To check high runoff and low infiltration, and to improve ground water levels, check dams and percolation tanks can be constructed. The perennial springs, with proper engineering designs can become more accessible. Roof water harvesting can access the heavy rainfall water. There is not a single solution to this problem. Whatever the scheme adopted, community participation is necessary. Future projections of water needs should be made to decide the priorities, related to alternative sources and schemes.

B. Health Education

- Education has to be given, regarding care and upkeep of water sources and prevention of water stagnation and contamination.
- Awareness of water-health-disease links, must be encouraged.
- Hygienic handling of water storage : (keeping water covered, using ladle, use of chlorine tablets at home, bleaching powder for wells etc.) has to be popularized.

C. Research : Possible Areas

- The conjunctive use of surface and ground water resources.
- Design for source development and field applications.
- Sociological studies on attitudes towards water and water sources.

- Impact of safe water sources on health and economics of society.
- Study of traditional remedies to purify water.

2.2 RAPID APPRAISAL OF HEALTH NEEDS

2.2.1 INTRODUCTION

Health and development being inextricably bound together, BAIF integrated a primary health care programme in its overall Tribal Rehabilitation Programme. A rapid appraisal of the health situation carried out in 1990 in the project area provided first-hand information.

2.2.2 METHODOLOGY

A flow chart and a schedule were developed to guide and assist the survey team. The methodology used is given below.

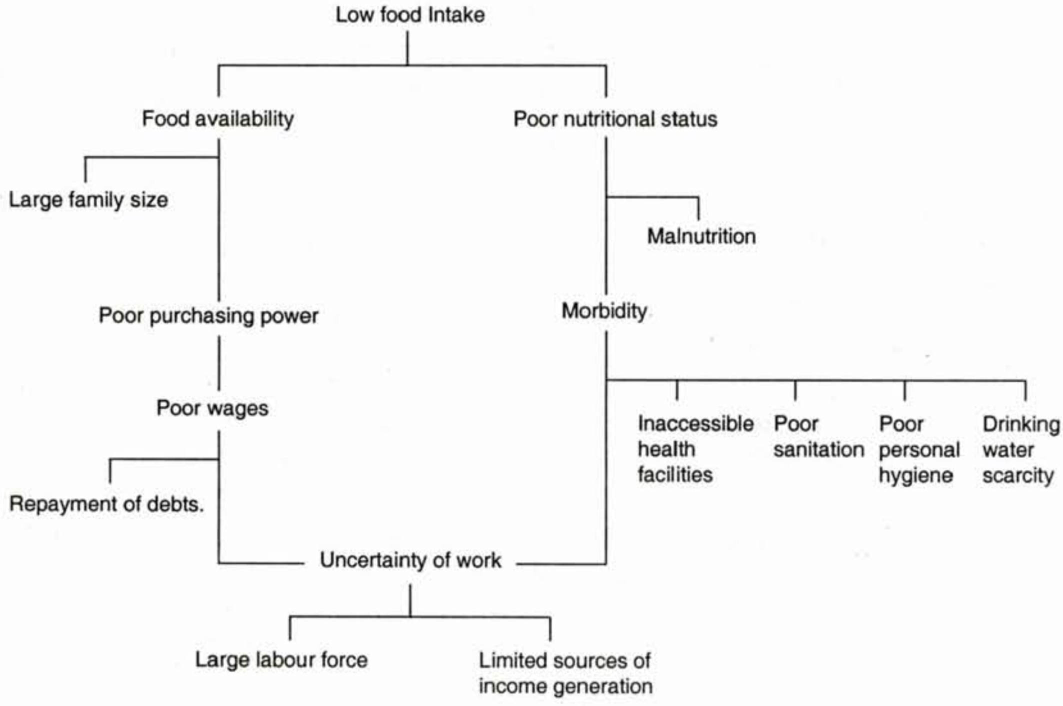


FIGURE 2.1 : FLOW CHART OF FACTORS HUMAN HEALTH, FOOD AND LIVELIHOOD IN AKOLE TALUKA.

- **The survey team.** This comprised doctors and BAIF's RDO's (Rural Development Officers). As well, information generated in a small survey by the B. J.Medical College, Pune, was utilised.
- **Mode of data collection.** The pattern of illness emerged mainly through the diagnositic camps held. Perceptions and feelings of the villages were expressed in discussions by village sarpanch, gram sevak (government representative at the village level), health worker, the elders, school teachers etc.

- **Duration of the study.** The total study period of 6 months was divided into - I) A planning phase of two weeks. In this, the needs for the study were identified, the schedule designed and the team was formed. II) Diagnostic camps and intensive field work were spread over the 5 months of the implementation phase. III). The priority areas for future interventions were defined during the information analysis and report-writing phase of the last 2 weeks. The study covered all the seasons and climatic conditions.

- **Selection of villages.** All the selected villages in the project area were in the interior, far from urban influence.

- **Secondary data collection.** Libraries, the meteorological observatory, BAIF's survey on the water-supply situation. Hospitals and primary health centres served as sources of secondary data.

Doctor treating a village women during the Health Camp organised by BAIF

2.2.3 RESULTS

The results of the rapid appraisal are given below.

A Geography of the region. The study area was 300 sq km and is in and around 30 km from the Bhandardara Dam. It is part of the Western Ghats. The ground is hard rock Deccan trap basaltic formation with soil cover in the valleys, but exposed rocks on the slopes. The forest cover is almost nil now. The rainfall is heavy, but water infiltration is negligible.

B The people. The Mahadeo Koli, a Scheduled Tribe, form approximately 90% of the population. The people clothe simply and women use the traditional garments. During the monsoon, the people have agricultural work, but otherwise especially men can be seen lazing around, which suggests underemployment.

C Village scenario in brief. The villages are small, compact, on hilltops, with sloping fields around. Houses are close together. The roads are unclean (garbage, dung), small and both unmetalled and metalled. The village school and the temple are the prominent buildings.

D Housing. With a rare exception of cement-concrete, all houses are made of stone and/or mud, roofs with tiles and floors/walls plastered with cowdung. There are two or three small, dark rooms and ventilation is minimal. Cooking is done on a chulha or in slightly affluent families on a kerosene stove. There is no smoke vent, no soak-pits or kitchen gardens and the sullage floods on to the street. All villages have electricity, but power cuts range up to several hours per day. Once the cattle were kept inside the house, but separate sheds are being built now.

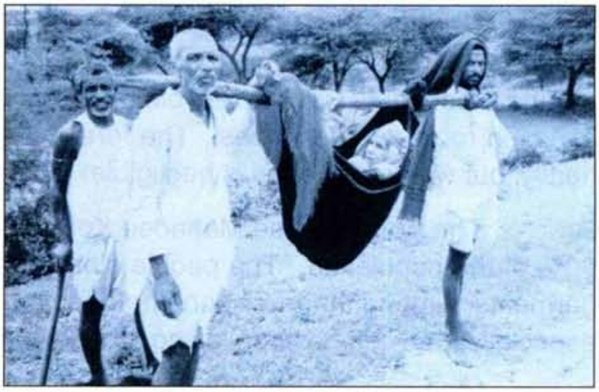
E Water facilities. Due to accute scarcity, any and every available source is used. The rainfall is heavy, runoff is high as the infiltration rate is very low. All borewells with handpumps have gone dry. Piped water is supplied only to three villages. Getting water, is drudgery. All chores are performed around the water source. For stored water in houses, ladles are not used.

F Waste Disposal. Open spaces and fields are used for defecation. Latrines built under Indira Awaas Yojana were never used. There are no biogas plants and only occasionally compost pits and soak pits are seen. The proposed aashram school plans have attached latrines.

G Village schools. Except for two villages, all other villages have schools up to 4th Standard and in two villages up to 7th Standard. The dropout rate is high, especially in the case of females. The 1981 census indicates very poor literacy rate. There are 2 to 3 teachers per school; most of them stay at nearby towns.

H Anganwadi / balwadi. There are *anganwadi* / *balwadi* in each village. Their actual functioning, however does not stand close scrutiny. According to the caretakers, 40-60 percent of the number enrolled attend daily. A supplementary food, "*sukhdi*" (a mixture of roasted wheat, *horse gram* and *jaggery*) is usually provided at mid-day to children, which also becomes an incentive to parents for enrolling their children in school.

I Communication facilities. Except Ambevangan and Dongarwadi, each village has a metalled or unmetalled approach road. State transport buses come at infrequent intervals. Mostly bicycles have replaced the bullock-driven 'gasha'. A few families own a moped / motorcycle. Manhere, *Devgaon* and Pimperkane have post offices, but only Pimperkane has a telephone. The transistor radio is universal. Most villages have a community television.



Emergency mode of travel

J Occupation. Farming is the main occupation and the land holdings are marginal (average. 1-5 acres). Milk is produced and sold to the co-operative milk society. "*Khava*", a concentrated milk, is also prepared for selling. There is a grocer's shop in each village. Goods are obtained on credit from them. Blacksmiths (4 to 5 villages), carpenters (all villages), cobblers (3 villages), a potter (1 village) are other artisans. Men from 1 or 2 families from each village are employed in government jobs.

K Income. The incomes are very meagre, due to low agricultural productivity. Paddy is the main crop. Pulses, groundnuts, or vegetables are cultivated by a few. Only those who are in government jobs have a regular income. Loans can be procured from public sector banks and a few facilities are obtained from the government as members of a scheduled tribe.

L Medical facilities

- *Traditional medical practitioners.* There are 23 'vaidus' (traditional medical attendants) in 13 villages. They use a combination of herbal medicines and rituals for curative purpose. Traditional birth attendants (TBAs) are only for conducting births. Out of the 21 TBAs in the area, only 2 were trained by the Shendi Primary Health Centre (PHC).
- *Government health facilities.* Two PHCs at Shendi and Ladgoan fall in the project area. Though only Chichondi is under the PHC at Shendi, people from other villages also go there. It has only one medical officer, who is over loaded with OPD work. A couple of others are paramedicals. The PHC at Ladgoan has no facilities as yet. The medical officer, residing at Rajur, makes daily visits. The paramedical workers, who are supposed to be in the villages daily, go there infrequently for immunisation, antenatal and postnatal care. The painted information, slogans and health education are hardly any use, on account of the low literacy. In all, the PHCs are having limited imputs. People rush to Pune or Nashik, if need for a detailed examination is felt. The animal parasite incidence (API) is more than 2 in the area. DDT/Malathion is sprayed once a year and a malaria worker comes just once in a while.
- *Private practitioners.* The practitioners of various systems are stationed at Shendi. They charge Rs. 10/- per consultancy. Due to their personalised approach, they are quite popular.

M Morbidity pattern. Malnutrition is the major cause of morbidity. The B.J. Medical College examined approximately 600 pre-school children. Protein energy malnutrition of all grades was 50% with severe grades around 10%. All the cases of PEM are only *Marasmus. Kwashiorhor* was not observed. Elders too, suffer malnutrition. Anaemia is common, especially among pregnant women. Iodine deficiencies are not common. Cretinism was seen in a girl aged 11. Deficiency of vitamin B complex is universal in children. Diarrhoea pervades all age groups. Cholera, which spread in a nearby area in July, 1990, does not affect this area. Cases of enteric fever, chlormycetin-resistant typhoid and viral hepatitis were also reported. Infections of the upper respiratory tract, pneumonia and bronchitis (in children) come with the monsoon. During the summer, acute skin infections, from scabies to impetigo and taeniasis, are rampant.

Though leprosy was noted as a major communicable disease (130 cases), the patients seemed to be well adjusted and were not treated as outcastes.

Tuberculosis and malaria are also common. Surprisingly, DDT is sprayed in April-May, when malarial mosquitoes are not around!

Syphilis, a sexually transmited disease, is notable. The shyness of women prevented the estimation of gynaecological disorders. All deliveries are conducted at home and there are incidences of purperal sepsis and stillbirths. Two cases of non-insulin-dependent diabetes mellitus and one case of grand mal epilepsy were diagnosed. Most of the morbidity is preventable. It comes through conditions rooted in poverty, which can be changed.

2.2.4 CONCLUSIONS AND RECOMMENDATIONS

Solving the problems of poverty and livelihood would improve the health situation. In addition, there are certain priority areas, where action is needed.

- **Provision of safe drinking water.** In all the villages, first and foremost, adequate water resources have to the developed. There is no single solution. The surface water runoff should be checked and infiltration increased. Afforestation is needed urgently.
- **Sanitation.** Soak pits (sullage), compost pits (house hold waste), and latrines (human waste) are all necessary to bring personal hygiene and cleanliness to the fore.
- **Proper Nutrition.** It needs to be ascertained that the additional income generated would be utilised for an increased and a properly balanced food intake. This, along with the concept of the kitchen garden has to be taught to villagers.
- **Housing.** Given the present, crowded condition, very little can be done. Nonetheless 'smokeless *chulhas'* can be introduced and demonstrated.

  The task is formidable. A family-centered approach could be adopted. Individual family health improvements would contribute to upgrading of the health status of the whole community. Health education is the most important priority, which would lead to awareness about health problems, their causes and solutions. The role of 'prevention' has to be inculcated. Meanwhile, as mentioned above, working in the priority areas would reduce the morbidity load. These villages are remote and therefore self reliance in basic health needs to be emphasised. A primary health depot can be run by a group of people well-informed about minor health complaints.

A good referral system is necessary. Each level of referral (starting from PHC) should acknowledge and manage the incoming cases. The better components of traditional medicine can be encouraged. Traditional practitioners (including TBAs) can prove a good resource for transmitting health messages.

Community participation in the health scheme is essental. Only a programme run by popular consensus is truly adopted and appreciated.

Medical and social research should continue. The ultimate purpose of the research would be to develop a replicable model.

◆◆◆◆

3: BASELINE DATA

Secondary data collection from available governmental records, supplemented by actual surveys in the area, was initiated in the first year of the project. Information available included climatic data from the Meteorological Department, topographical maps from the Surveyor General, and soil survey maps and satellite imageries from the Space Application Centre. Surveys were conducted for socio-economic factors, topography and preliminary information on geohydrology of the area. Details of data collected and analysed are given below.

3.1 SOCIO-ECONOMIC BASELINE DATA

Population Distribution

The total population residing in the study area is 3239 (January, 1993). Of these, 54.03% are males while 45.97 % are females.

The age distributions show that 15.07% belong to the under-five age group, 23.56% belong to the five to fifteen age group while as many as 39.67% belong to the fifteen to forty age group. Only 1.45% belong to the above sixty age group. It may be concluded that the population of this area is dominated by younger people.

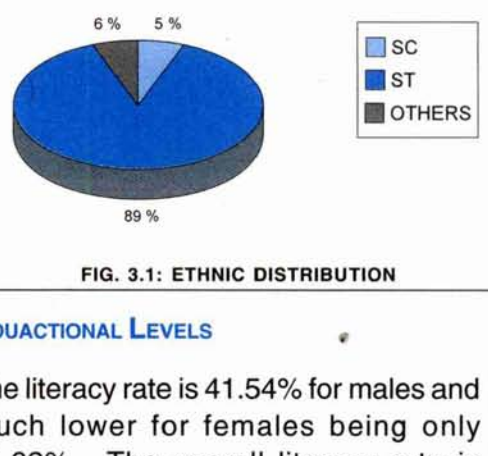


FIG. 3.1: ETHNIC DISTRIBUTION

Of the total number of households in these villages, 89.34% are Scheduled Tribe households while 4.92% are Scheduled Caste households. These are the poorest sections of Indian society. Details of the demographic information are provided in **Figure 3.1.**

Eduactional Levels

The literacy rate is 41.54% for males and much lower for females being only 11.62%. The overall literacy rate is 28.10%.

Of the literate males, 30.53% can only read and write, 38.81% have studied up to the primary level and 15.33% up to the secondary level. As many as 13.84% are matriculates and 1.49% have studied up to the graduation level or above.

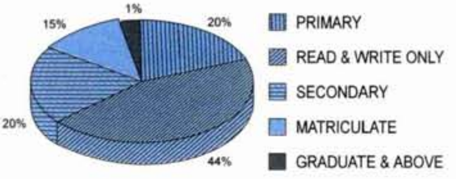


FIG. 3.2: EDUCATIONAL STATUS

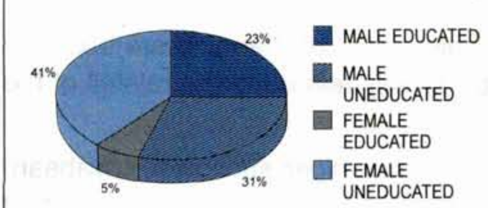


FIG. 3.2A: SEX-WISE EDUCATIONAL STATUS

In case of women literates, 31.79% can only read and write, while 58.38% have studied up to the primary level. No female has studied up to matriculate level and above.

The literacy rates are low in general, but extremely low for women. Details of the educational levels are provided in **Figures 3.2 and 3.2A.**

Land-Holding Pattern

Of the 494 households covered in the area, only 3.44% are landless. The largest group holds between 2 to 4 hectares of land. Nearly 31% of the families fall in this category. 10.32% of the families hold more than 8 hectares of land.

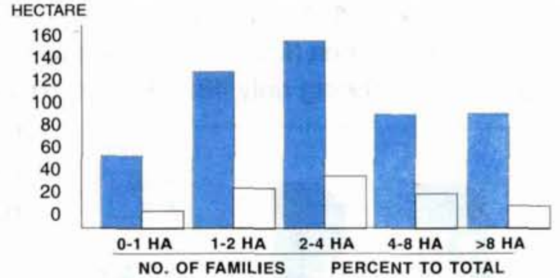


FIG. 3.3 :LAND-HOLDING PATTERN

The average land held per household is 4.28 hectares. Details regarding the land-holding pattern are provided in **Figure 3.3.**

Livestock Ownership

Animals owned by the inhabitants of this area include bullocks, cows, heifers, buffaloes (male and female), female goats, sheep, and hens. The average number of bullocks owned per household is 0.75. The average number of cows owned is 0.51. Very few sheep, male buffaloes and heifers are held by the residents of these villages. In general, the livestock resource is poor and is continuously decreasing. Details of livestock ownership are provided in **Figure 3.4.**

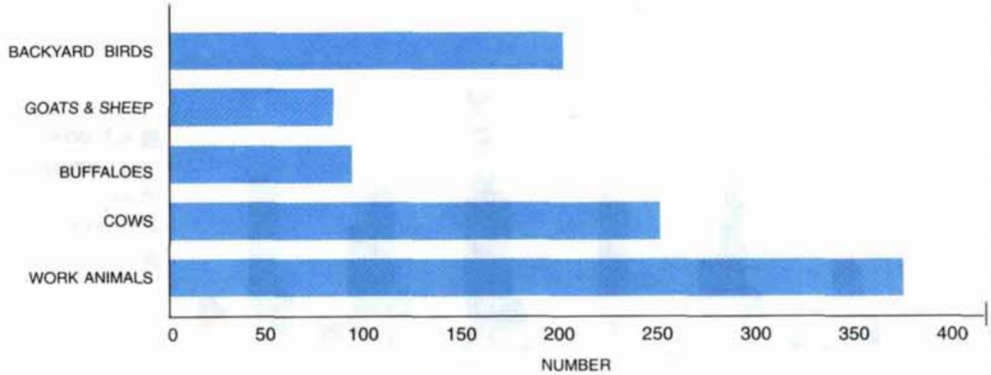


FIG. 3.4 : LIVESTOCK RESOURCES

AGRICULTURE

Both *kharif* (June - September) and *rabi* (October - January) farming are taken up by the farmers in this area, with the *rabi* crop directly related to the rainfall of the year and its distribution.

In the *kharif* season, rice, *ragi*, *'varai'*, maize, groundnut, *niger*, sunflower, soyabean, horse *gram*, beans, black *gram*, pigeon-pea, cow-pea, *gram*, green *gram*, and local grass are cultivated.

In the *rabi* season, wheat, maize, pearl millet, rice, *'shalu'*, sorghum, *'aawali'*, groundnut, *niger*, sunflower, *gram*, horse *gram*, beans, lentil, black *gram*, cow-pea and pigeon-pea are cultivated.

The average production per hectare is 3899.17 kg for hay grass, 1196.05 kg for paddy rice (*kharif*), 1000 kg for maize (kharif), 900 kg for green *gram* (*kharif*) and 812.5 kg for cow-pea (*kharif*). The average production per hectare is low for soyabean and sunflower, being only 48.45kg and 61.22 kg respectively.

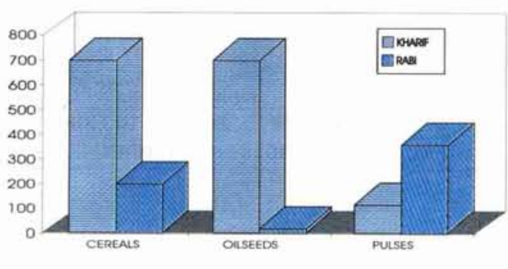


FIG. 3.5 : AGRICULTURAL PRODUCTION

In the *rabi* season, the average production per hectare is 4000 kg for *niger,* 1466.67 kg for rice, 900 kg for green-*gram* and 726.30 kg for wheat. The average production is low for cow-pea, being only 150 kg per hectare.

The productivity per hectare is lower than the national average in case of all cereals and pulses and most oilseeds. Only in case of niger the production per hectare is on par with the national average.

In the *kharif* season, the largest area is under rice, local grass, groundnut and *ragi*, while the smallest area, cultivated in the *rabi* season, is under maize, pulses other than horse *gram*, pigeon-pea and soya-bean. In the *rabi* season, wheat and *gram* are the main crops sown. Details regarding agricultural production are provided in **Figure 3.5.**

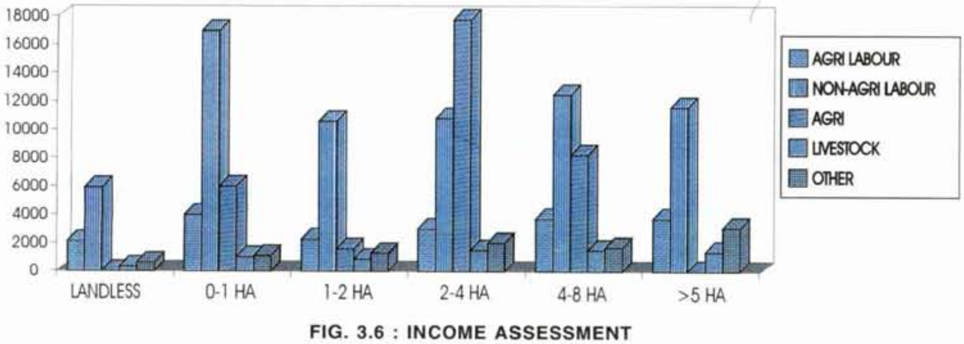


FIG. 3.6 : INCOME ASSESSMENT

The average household income for the project area for the year is extremely low, being only Rs.821.45. The various sources of income included agricultural labour, non agricultural labour, agriculture and livestock. The average annual income (Rs.2926.03) is the largest for the farmers owning more than 8 hectares of land. The annual household income is the lowest (Rs.465.77) amongst the category of farmers, owning between 2 to 4 hectares of land. Details regarding the various sources of income are provided in **Figure 3.6.**

3.2 METEOROLOGICAL DATA

The meteorological data of the study area is one of the most crucial inputs and was collected on following important climatic variables:

- rainfall
- temperature
- humidity
- wind
- evaporation

There are four meteorological stations, established by the Government of Maharashtra in the vicinity of the project area, located at villages of Waki, Randha, Bhandardara and Akole. Only the daily rainfall data is available from these stations. The data on temperature, humidity, wind speed and evaporation was collected from the nearest meteorological station at Niphad near Nashik.

Meteorological Stations Established Under The Project

As the area is subject to very large, climatic variations, it was necessary to establish meteorological stations in the watershed areas under study. Two meteorological stations were established in two project villages, *viz.* Manhere and Titvi. The details of equipment installed at the field stations are given in the **Table 3.1**.

TABLE 3.1 Meteorological Equipment At Field Stations

S.No.	Equipment	Description
1	Cup counter anemometer	Indicates the total run of wind past an observation point in km/s.
2	Rain gauge	Indicates rainfall.
3	Open pan evaporimeter	Measures evaporation rates..
4	Minimum-maximum thermometer	Indicates daily maximum and minimum temperature.
5	Wall thermometer	Indicates temperature.
6	Stevenson's screen	Designed to shield all types of meteorological thermometers and hygrometers.

3.3 TOPOGRAPHICAL AND GEOLOGICAL MAPPING

The topographic sheets of the area prepared by the Survey of India were procured. But as these maps are at 1:50,000 scale with 20 m contour interval, they are useful only for general area planning. For detailed micro-level planning, topographical maps on smaller scale with a 5 m contour interval are required. A detailed topographical survey was carried out in the study area. The topographical maps at 1:4000 scale were prepared with a 5 m contour interval. The information on slope groups was derived on the basis of the maps with Scale 1:50,000. A slope group map was prepared with the help of GIS software, using three main slope groups as detailed below in **Table 3.2**. The slope classification map is given in **Figure 3.7.**

TABLE 3.2 AREAS UNDER DIFFERENT SLOPE GROUPS

Sr.No.	Slope Group (Ha.)	Area	% age To Total Area
1	0 to 10%	198.36	33.80
2	10 to 20	199.45	33.99
3	30 % And Above	188.98	32.21
Total		**586.79**	**100.00**

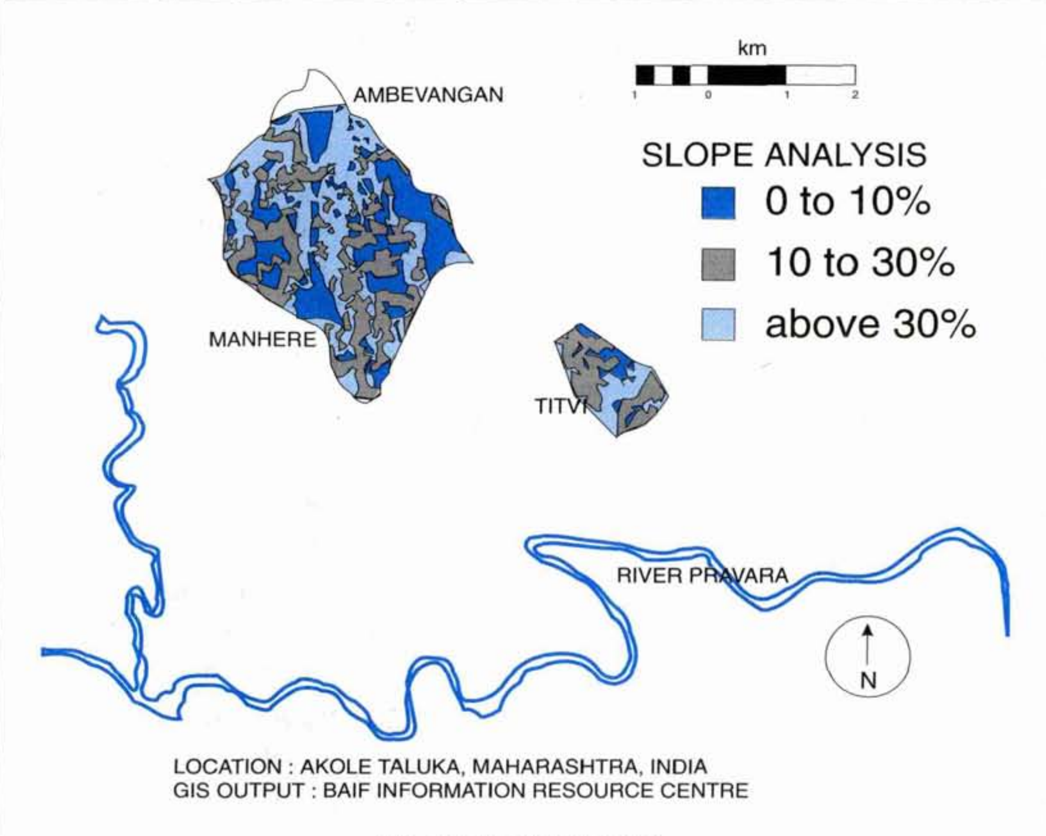


FIG. 3.7 SLOPE GROUP MAP

LAND CAPABILITY

The data on the land capability classification of the watershed area was procured from the Soil Survey Department of the Government of Maharashtra. The data were entered in a separate database and a land capability map was drawn up, using GIS software. The data were analysed and the details are provided in **Table 3.3.**

TABLE 3.3 LAND CAPABILITY CLASSIFICATION

Sr.No.	Land Capability Class	% age To Total Area
1	I	-
2	II	32.36
3	III	5.11
4	IV	29.31
5	V	-
6	VI	26.02
7	VII	7.20
8	VIII	-
Total		100.00

As seen from the above table, nearly 62% of the total watershed area falls under Land Capability Class IV and above. The main characteristics of areas under these classes are:

- shallow soil depth
- low permeability
- steep slopes
- low water holding capacity
- heavy rate of erosion

The information on slope groups and land capability has a direct bearing on surface and ground water. These data were useful for planning a detailed geological and geohydrological study.

The existing geological maps prepared by the Geological Survey of India were procured. The published geological data of the study area were collected and compiled to give a better understanding of the geology of the study area.

3.4 GEOHYDROLOGY OF AREA

Information about dug wells, borewells, percolation tanks and checkbunds in the three villages of the Akole region has been collected. The details are as follows :

INVENTORY OF DUG WELLS

Information about existing dug wells in the project area was collected through an intensive field survey. The information collected in the first year was later updated. (See **Annexure 1**.)

There are total 46 dug wells in the study watershed area. Most of the wells are shallow to medium depth wells. The average depth is 6.94 m, ranging from maximum 15.85 m to 2.43 m.

There is a very high variation of water level in wells during different seasons. As most of the wells are located in the valley portion, the wells are full to their maximum capacity during the monsoon. The water level drops in the post-monsoon season and in summer most of the wells are dry.

Bore Wells

Data about borewells drilled by the State Government in project villages is presented in **Table 3.4.** The details have been obtained from the GSDA office at Ahmednagar.

TABLE 3.4 Details Of Borewells In Akole Area

Village	Date	Dia in mm.	Depth in M	Casing M	Status Dry/P.Y.*/ Successful borewells	No. of borewells/ Successful borewells	Population 1981	Total Area in Hectares
Titvi	30.05.83	150	52.15	3.05	P.Y.	3/0	595	988
	02.05.83	150	73.65	6.10	Dry			
	24.03.89	150	60.00	3.05	Dry			
Manhere	14.10.79	100	68.45	4.5	Dry	3/2	1106	768
	13.09.80	150	83.82	3.05	3375 LPH	(4/3)		
	08.09.90	150	60.00	-	597 LPH			
	22.10.91	150 (Hydrofractured)	61.00	3.05	P.Y.			
Ambev-angan	11.10.79	100	60.96	3.05	P.Y.	5/3	568	693
	24.05.83	150	69.15	6.10	597 LPH			
	04.05.83	150	73.65	6.10	3380 LPH			
	12.05.84	150	76.00	3.05	Dry			
	07.03.90	150	61.00	3.05	597 LPH			

* P.Y. = Perennial Yield.

From GSDA records, there are in all 11 borewells in the three villages, of which only 5 borewells have encountered water. Their present condition is unclear, as most of the handpumps installed are not in working condition.

3.5 REMOTE SENSING DATA

In the recent years remote sensing has emerged as a powerful technique for providing reliable information on natural resources at different levels of detail. BAIF Development Research Foundation, Pune and Space Application Centre, Ahmedabad jointly took up a water resources development programme, using satellite data for a group of villages in Akole Taluka of Ahmednagar District.

The main objective of this collaborative effort had been to use remote sensing data to develop a methodology for micro-level planning for sustainable development of natural resources in Akole tribal area.

The thematic maps on 1:25,000 scale have been prepared and integrated to suggest sites for water resources development and this information has been transferred on cadastral level maps (1:10,000) for three priority villages viz. Manhere, Ambevangan and Titvi selected for this study.

In addition to this, information was also obtained from the Maharashtra Remote Sensing Application Centre, Nagpur in the form of maps (1:50,000) for the Akole Taluka.

3.5.1 INFORMATION OBTAINED FROM SPACE APPLICATION CENTRE, AHMEDABAD

Data Used

Following data was used for preparation of base maps.

I. Satellite Imageries

- IRS LISS II (19th February 1990, 4th March 1989)
- SPOT MLA (7th November 1990, 9th May 1988)
- SPOT PLA (B/W) (12th November, 1988)

II. Collateral data

Survey of India Toposheets (scale 1:50000) cadastral level village maps.

Steps involved while preparing maps:

1. Data procurement
2. Base map preparation
3. Preliminary interpretation of satellite Imagery
4. Field checks (Ground Truth)
5. Final interpretation
6. Final mapping

Survey of India (SOI) topographic maps on a 1:50,000 scale and satellite data (IRS-1A LISS-II) FCC SPOT PLA black & white and SPOT MLA FCC, in the from of 9" transparency were procured.

Since information for the implementation programme is required at a cadastral level (1:10,000), interpretation of satellite images at the largest scale possible, that is, 1:25,000, has been considered optimum. A base map on 1:50,000 scale using SOI topographic map indicating longitude, latitude, major drainage network, roads, location of villages etc. was prepared. Diapositive (transparency) of this base map was made. Using a high magnification enlarger (HME), which permits magnification up to 45 times, a diapositive of the base map on a 1:50,000 scale was enlarged to 1:25,000 scale, after which the base map was prepared.

The transparencies of satellite images were enlarged to 1:25,000 scale using the HME. Thematic information was transferred to the base map. On the basis of tone, texture, shape, size, pattern, association etc., various theme categories such as valley fills, linear features, various categories of wastelands and various forest densities were delineated. Interpreted overlays were superimposed over multidate images and additional information was also transferred on the overlays. Using this methodology, six base maps were prepared for the Akole area. The list of maps is provided below. These base maps have been used for further studies taken up under the projects.

Maps Obtained From SAC

A. Slope map (1:25000)

B. Hydrogeomorphological map (1:25000)

C. Forest density map (1:25000)

D. Sub watershed / Drainage map (1:25000)

E. Suggested sites for water resources development (1:25000)

F. Water resources and wasteland development sites for Manhere, Titvi and Ambewangan villages (1:25000)

Contents Of Base Maps

A. Slope Derivation

The slope was derived from 20m contour interval toposheet. The data source for this purpose was 1:50,000 Survey of India topographical maps. The slope was derived on a grid (1cm x 1cm) basis. Each grid was 25 ha at 1:50,000 scale. It was assumed that each grid would have a unique and representative slope value. Thus, two elevation points (maximum and minimum) were selected in each grid. It was assumed possible to derive the maximum slope in each grid and thereby to show the maximum limitation with respect to topography in the grid.

B. Hydrogeomorphology

The usefulness of satellite data is well established in mapping of fractured and weathered zones, which are usually the zones of localisation of groundwater in hard rocks and certain geomorphic features such as valley fills, alluvial fans, etc. which often form good aquifers. Thus, remote sensing helps to narrow down the areas for the search of ground water for detailed ground-water recharge and rain water harvesting structures.

Using satellite images, a hydrogeomorphological map of 1:25,000 scale was prepared for Akole Taluka, depicting various hydrogeomorphologic units, such as valley fills, lineaments and escarpments of the Deccan Plateau. It was found that typical aquifers with sufficient ground water are absent. The main solution to solve the water problem is to develop water resources by constructing rainwater-harvesting structures. Keeping this in view, a map showing suggested sites for water resource development was prepared.

C. Forest

The forest boundary was taken from the SOI topographical maps on 1:50,000 scale and was transferred to the base map. A density based classification was adopted to define the present condition of the forest. Three categories were recommended: closed forest (>40% canopy cover), open forest (>10% to <40% canopy cover) and degraded forest (<10% canopy cover).

D. Sub-watershed Boundary

A sub-watershed is a hydrological boundary suitable for any developmental action plan. An area under one sub-watershed is generally not influenced by the hydrological, soil and land parameters of the neighbouring watershed. Therefore, the development plan suggested for a watershed will be unique and independent of others. In the present study, the upper and lower limits of the sub-watershed were assumed to be 2500 ha and 1000 ha respectively. For drawing the sub-watershed boundary, the drainage and elevation contour information were utilised from the 1:50,000 SOI topographic maps. In all, there are 14 sub-watersheds covering the area of Akole Taluka.

E. Sites for Water Resource Development

By integrating the available information, the sites for water resources development were suggested.

3.5.2 MAPS OBTAINED FROM MRSAC, NAGPUR

The Maharashtra Remote Sensing Application Centre, Nagpur provided the following maps of Akole taluka (1:50,000 scale) so as to use this data for micro level planning.

A. Soil Erosion Status Map

This map gives the information on physiographic units and slope, land use/land cover information, soils erosion extent (slight, moderate, severe, very severe) Data used :

1. IRS LISS II (8th May 1989, 17th April 1989)
2. Soil Survey Organisation (M.S.)
3. NBSS and LUP (waste land maps)
4. Forest maps

B. Hydrogeomorphological Map

This gives information about the geomorphic unit; whether it is of fluvial origin (valley fills, ravines) or structural origin (highly/moderately/slightly dissected basaltic plateau, plateau top) e.g. dyke, lineament, fracture line valley, escarpment or butte. Also the map provides description of the geomorphic unit and groundwater prospects in the area.

Data used : IRS LISS II (28th December, 1988)

C. Surface Water Bodies / Drainage & Watershed

On this map, river basins, watersheds, subwatersheds microwatersheds and reservoirs are depicted.

Data used :

1. Survey of India toposheet (1:50,000)
2. IRS LISS II (23rd October, 1988; 28th December, 1988; April 1989)

D. Land Use / Land Cover Map

A classification of land use was provided on this map, whether the land is agricultural land, forest land, or wasteland.

Data used:

1. IRS LISS II (18th January, 1989; 22nd October,1988; December, 1988; 23rd October, 1988)

E. Transport Network and Settlement Location Map

Information about roads, railways and settlements was given.

Data used:

1. SOI maps
2. Road map prepared by P.W.D. Ahmednagar

F. Slope Map

Slope categories of 0-1%, 1-3%, 3-5%, 5- 10%, 10-15%, 15-35% and more than 35% were shown in the map.

Data used :

SOI toposheet :1,50,000

Use Of Remote Sensing Data

Remote sensing was supplemented with ground data collected during field studies. These data were used for geological, hydrogeological and hydrological studies planned under the Conjunctive Water Use Project.

◆◆◆◆

4: INDIGENOUS KNOWLEDGE

4.1 HISTORICAL BACKGROUND OF WATER SHORTAGE

The elderly among the tribal and rural people provided a useful perspective on the possible connection between changing patterns of land use in Akole Taluka and the widespread conditions of water shortage, which created the need for this project. Their views were recorded at different times during the project term, but most notably during a series of public meetings, held in November, 1995.

At these meetings, elderly villagers were asked how the area had changed, since the times of their fathers and grandfathers. There were strong similarities between the collective responses, made at each of the collaborating villages. Formerly, the area was covered with dense forest, which gradually was removed by outside business interests and also by the local people themselves. In those days, water was plentiful and agricultural production good, but these conditions did not last. Water became increasingly scarce, soil quality deteriorated, and crop yields declined to a subsistence level.

The generalized, oral history of land use in Akole Taluka, supplied by villagers, is in good agreement with the contemporary accounts by government officials, notably those of Tytler (1848, reprinted in Fletcher, 1888), Bombay Government (1884), Fletcher (1886, 1888), and Hey (1916). The historical perspective of land use that follows is based on parts of these reports.

Commercial logging and local cultivation practices had severely depleted the forest reserves of Ahmednagar District by 1884 (Bombay Government, 1884). At that time, a general summary of land use was: arable, 74.6% of the district; unarable, 9.8%; forest, 12.5%; and other, 3.1%. The amount, designated as forest, was land held as forest reserves, so that only a smaller proportion was actually covered by forest.

Akole Taluka contained up to a quarter of the total forest reserves of the district and in 1884, the Forest Department was continuing to harvest as much timber as the depleted reserves could supply. At that time, a general summary of land use was: arable, 56.9% of the taluka; unarable, 14.0%; forest, 28.4%; and other, 0.7%.

A type of shifting cultivation, known locally as *dalhi* (*kumri*), was widely practised in Ahmednagar District during the mid-1800s. This began during the cold season with the clearing of brushwood and the cutting of branches from larger trees. These were spread over small plots on the steep hillsides and were allowed to dry until the end of the hot season, when they were set on fire. The fertilized soils were loosened by means of a hoe after the rain and seeds were sown. The main crops were *nagli*, *jvari*, and *sava*. No transplanting of seedlings was required. A second crop was planted the following year. Then the land was left fallow for six to ten years.

As well, cultivation of the plots was commonly continued under the *rab* system, which is employed at present. This involves the drying and eventual burning of branches and leaves on small plots of land, followed by the planting of seeds in the ashes, after the first fall of rain. The seedlings later were transplanted in the fields. This approach was used for rice and for dry crops.

As much as 30,000 acres of land in Akole Taluka was under *dalhi* cultivation in a given year during the mid-1800s. This approach to the replacement of natural vegetation with planted crops was prevalent in 40 to 50 villages of Akole Taluka in 1849. However, *dalhi* cultivation had decreased significantly across the district as a whole by the 1880s.

Reporting on the First Revision Survey, Fletcher (1886, 1888) noted that the amount of land under cultivation in Akole Taluka had increased steadily, since completion of the initial settlement survey in 1848. It is noteworthy that Akole Taluka was not affected to a major extent by the famine of 1876.

In his report on the Second Revision Survey, Hey (1916) stated that Akole Taluka was the only one with significant forest reserves remaining. However, the survey also indicated that the good agricultural lands of the area had been occupied for a long time and that the ṯaluka had reached its limit of profitable cultivation.

4.2 HISTORY OF TRADITIONAL PRACTICES IN AGRICULTURE

Prof. Simpson in a village meeting

The present tribal population moved into the project area about 150 years ago, after defeating the original inhabitants who were displaced. At that time, the area was surrounded by thick forest. The produce from it was the main source of food for the tribal people. Before independence, the forest was cut down and burnt by traders to produce charcoal. The main basis for survival of the tribal people thus became scarce. Hence the people started cultivating crops. Initially, the main water streams were arrested by stone bunds. The land on the banks of streams was very fertile and suitable for the cultivation of paddy. This was mainly due to the deposition of biological waste, such as tree leaves and sticks. This compost is known as '*marwa*' in the local language. Tributary streams were also developed. However, they lacked a constant supply of waten, and gaue a low-yield variety of paddy.

4.3 TYPES OF LAND

The land near the main stream is known as '*garvi jamin*' where high-yielding and long-duration paddy is grown. Land around the tributary streams is called '*halwi jamin*' where lower-yielding, short-duration paddy is grown.

The land between the main streams and their tributaries was composed of '*murum*', i.e. soft rock (weathered bedrock), due to constant soil erosion. This was developed by terrace bunding, locally known as '*taali*'. These *taalis* were found suitable for legumes and oilseeds such as *khurasni* (niger / *Guizotia abyssinica*), *kulith* (horse *gram* / *Dolichos biflorus* L.) and groundnut (*Arachis hypogaea* L.). *Taali* yielded good output, even with minimum effort from the villagers.

4.4 LAND USE PATTERNS

The local land classification has the following categories: land for habitation, cultivation, grazing and waste land. The land used for cultivation mainly consists of the types of soils, shown in **Table 4.1**. The land-use pattern, soil type and seasons show interlinking.

TABLE 4.1 FARMERS' CLASSIFICATION OF LAND AND CROP PATTERNS

Type of soil	*Kharif*	*Rabi*	Summer
Silt deposits (in main stream)	Paddy, beans	Wheat, Bengal *gram*	
Brown soil (near tributaries)	Paddy, vegetables	Oils seeds, millets	
Newly terraced land (Soil and soft *murum*)	Millets, legumes	Oil seeds	
Bunds in area (soft *murum*)	Legumes	Oil seeds	
Rock / hard *murum*	Cultivation not possible		

4.5 CULTIVATION PRACTICES

Previously, soil erosion was arrested through bunds and the land was used to produce sufficient grain for the existing human population. However, the demand on available land has increased over the years with an increase in the population. Through the use of manure and farmyard manure, the fertility status of the soil was improved. '*Gomutra*' (cow's urine) was discovered to be a useful insecticide. It was also considered sacred. It was found that the sprinkling of *gomutra* generally restored sickly plants and creepers, which were believed polluted by human or non-human intervention. This practise was replicated for other plant life, including crops.

Similarly, *taag* (jute / *Corchorus capsularis* L.) was grown on the terraces and used *in-situ* as green manure by a process known as '*shidwa*'. This involves cutting mature jute, which is then buried. While vermi-composting as a technique was not known, there was an awareness of the significance of worms in agriculture and their cultivation in the field was practised. Use of cow dung with *marwa* gave good yields.

Crop rotation was followed to maintain a good quality of soil and to obtain increased agricultural production. The sequence was legumes (*kulith*) followed by lower millets (*nachni, sawa*), oil seeds (*khurasni*) and finger millets (*varai*). It was known that the biological wastes from these crops (leaves and sticks) help in the growth of each subsequent crop. A variant of the shifting cultivation method was used, in which one plot is used for cultivation, while another is used for grazing. This ensured good-quality fertiliser from the accumulation of cow-dung.

The tribals could name eight varieties of paddy crops. Crops were categorised by quality, weight, taste, and yield. Each variety was cultivated in different fields and was recycled by preserving them in the form of seeds.

Paddy varieties grown here are purely local and hence do not have English synonyms. They are: '*kalbhat*', '*takya*', '*jirwel*', '*kulpi*', '*varangal*', '*zini*', '*ambemohor*' and '*dhawlu*'. Each one has derived its name from its properties. For example, "*kalbhat*" means the one which is dark in colour, "*kala*" being the word for black.

Paddy nurseries are grown on level platforms and then transplanted on different types of land depending on the variety. Before sowing, seedbeds are prepared by burning dry leaves and twigs. The prepared beds are used only after the first monsoon showers.

The local varieties of rice, pulses, and oil seeds are the main crops in the area. The cropping pattern follows a definite order. The monsoon is the time when maximum agricultural planting and production takes place. Winter crops are possible, only when the monsoons are good. Summer crops are not possible.

4.6 PREDICTIONS ABOUT RAINFALL

There are some changes, which take place in nature and have been observed for years. These are used as indicators for rainfall prediction and are listed below:

- If mango and *jambhul* fruits ripen and fall down early in summer (early May), then early rain is predicted
- If '*sarda*' (chameleons), change to red from the usual brown and black colour, rain is expected within 10 to 15 days thereafter.
- The mating period of *kiwa* and *kumbha*, which are the local birds, starts 20 to 30 days before the beginning of rainfall.
- If ants are seen carrying their eggs to other places, rains are likely to commence within 8 days.

4.7 LOCATION OF GROUND WATER

The traditional practices for identifying ground water sources are given below:

- Vegetation on the ground appearing green in the month of April, ("*chaitra*" in the local language) is an indication of undedground water.
- It is believed that the "*umbar*" tree grows above and near a water source. The roots of the tree move in the direction of the water source beneath it.
- The "*paier*" tree grows on hard rock, just above a water source.
- If two hills are situated on a line running east to west, there are good chances of an underground water source between them.
- There is another traditional technique of locating an underground source of water. If vegetation remains green, even in the summer there is a good possibility of underground water. To confirm this, new earthen pots, filled with water, are placed at the four corners of the suspected area. The chances of underground water are good, if the levels of water in the pots are unchanged by the next morning. This is because dry land absorbs water faster, compared to land with a source of water beneath it.
- A mute or blind person can locate sources of underground water. It is believed that their disability is compensated by a sixth sense Apparently, this is true in 70 to 80% of cases, which has encouraged its practice.

4.8 SOCIAL CONSTRAINTS ON PROJECT IMPLEMENTATION

Tribals living in remote areas only rarely interact with other people. Their sporadic, external contacts have left them with an impression that all outsiders are exploiters. Hence, they are hesitant to develop any relationship with strangers. Similarly, their interaction with other officials has given them the feeling that outsiders are superior and local people are hardly worth anything. The first experience of project participants with tribals was not any different. They were very shy and suspicious of the intentions of the project teams. Fortunately, close interaction with them, combined with an emphasis on communication, helped to pave the way for establishment of a good working relationship.

Like most of their brethren, they think of short-term gains. So during the initial stages of the project, they showed a preference for measures like well deepening, construction of tanks and lift-irrigation schemes. But the long-term goal of the project was to find a methodology for optimum use of surface and ground water resources. Hence, it was a challenge to make them understand the significance of long-term objectives and to help develop foresight.

Some constraints on the implementation of experimental measures are illustrated here. The farmers were very reluctant and hesitant to undertake work in their fields, because they were apprehensive about the possibility of losing their property to outsiders. Secondly, the construction of farm ponds would lessen the area for cultivation and grazing. It was clear that unless they were convinced of the genuineness of these efforts, their participation could not be assured.

The tribals are also known for their local practices in agriculture, which are adequate to satisfy their needs in the short-term. For instance, cultivation on field bunds has been the usual practice to get the maximum, available land under crops. This leads to heavy soil erosion of bunds and ultimately the whole terrace becomes washed out. The practice of flood irrigation was employed, due to a lack of awareness of any alternatives. Free grazing is practised with no restriction on the movement of cattle. This hampers the growth of young plants and existing grasses.

Since then, micro-irrigation systems have been demonstrated in the area to make them aware of the optimal use of scare water resources.

4.9 GLOSSARY OF LOCAL TERMS

Marwa	-	Decomposed, biological material, deposited in a stream beds.
Garvi Jamin	-	Land near the main stream
Halwi Jamin	-	Land around tributary streams
Murum	-	Weathered bedrock
Taali	-	Terrace bunding
Khurasni	-	Niger /*Guizotia abhyssnica*
Kulith	-	Horse gram / *Dolichos biflorus* L.
Shidwa	-	Process of using jute for green manuring
Nachni	-	Nagli / *Elucaene coracana*
Sawa	-	A kind of millet
Varai	-	A finger millet
Umbar	-	*Ficus glomerata*
Jambhul	-	*Syzygium cumili*

Kalabhat, takya, jirwel, kulpi, varangal, zin, ambemohar, dhawlu are all rice varieties, grown in the study area.

◆◆◆◆

5: CAPACITY BUILDING

5.1 HUMAN RESOURCE DEVELOPMENT

Training, both formal and informal, has been a continuous activity right from the beginning of the project. Formal training in subjects relevant to the project staff was useful in implementation of the programme. It also helped initiate innovative ideas in water resource development.

TABLE 5.1 FORMAL TRAINING

Attended by	Subject	Conducted by
A. Long Duration (International)		
B.K. Kakade	Ferrocement Technology (1993)	AIT, Bangkok, Thailand
B.D. Pakhare	Postgraduate course in exploration, exploitation and management of groundwater resources (1995)	Hebrew University of Jerusalem, Faculty of Agriculture, Rehort, Israel
B. Short Duration (National level)		
Hydrogeologist	Ground water exploration	National Geographic Research Institute (NGRI), Hyderabad.
S.C. Kanekar	Interpretation of satellite imageries and use of remote sensing data	Satellite Application Centre, Ahmedabad.
Field officer (1)	Natural resource management with participation of local community	Centre for science and environment (CSE)
Field officers (2)	Data analysis and survey of watershed development	Yusuf Meherally Centre, Mumbai
B.K. Kakade	1. PRA/RRA Watershed development 2. Micro-irrigation	MANAGE, Hyderabad MCCI, Pune
Field officers (3)	Nursery raising	Central Research Station, Urulikanchan.
Field officer (1)	Ferrocement technology	Auroville,

In anticipation of future requirements, local youths from the community were trained in various soil and water conservation activities, in the first year of the project. This was useful during implementation of the experimental measures. There are now 3-4 trained teams in each watershed development activity. Areas covered under this kind of training are given in the following table.

TABLE 5.2 INFORMAL (ON-THE-JOB) TRAINING

Attended by	Subject	Conducted by
BAIF field implementation staff	a. Testing of soil permeability with the field permeameter b. Water table mapping. c. Testing radon levels in soil gas. d. Testing surface infiltration rates.	UW project team
Local community	Soil and water conservation techniques especially - gabion structures - checkdams - farm ponds - meteorological data collection.	BAIF
Village youths	Masonry and ferrocement	CRS, BAIF, Urulikanchan and BAIF Vansda campus.
Local community members	Watershed Management	Agricultural University (AU)

5.2 DISSEMINATION MEASURES

Two types of dissemination measures have been adopted to promote the transfer of project technologies.

5.2.1 DOCUMENTATION

The data generated during the experiments and results obtained have been shared with people of the project area to facilitate their implementation for improved agricultural practices. Successful findings have been compiled into booklets, manuals and brochures for widespread distribution to field and other personnel, and include:

- a manual on conjunctive use of water resources in the deccan trap area.
- a booklet on soil and water conservation structures in watershed development
- technical awareness brochures on ferrocement impervious gabions and roof water harvesting.

5.2.2 WORKSHOP AND SEMINAR PRESENTATIONS

Information gathered and results obtained have been shared at various national level workshops and seminars, as detailed in **Table 5.3.**

TABLE 5.3 WORKSHOPS AND SEMINARS

Attended by	Subject	Conducted by
B.K. Kakade and S.C. Kanekar	Seminar on Remote Sensing Applications	National Remote Sensing Agency, Hyderabad
B.K. Kakade	AFPRO National workshop on Participatory watershed management. Paper presented on "Capacity Building on Participatory Watershed Management".	AFPRO, New Delhi August 1995
B.K. Kakade	"Wasteland Development through Farm Forest" National workshop on experience sharing - Paper presented on "People's Participation in Watershed Development".	IFFCO, Udaipur March 1996
BAIF officers and representatives of other NGOs	Seminar on Geology and the Environment	BAIF, Pune, February, 1996

SEMINAR ON GEOLOGY AND ENVIRONMENT

The objective of the seminar was to enable participants to appreciate the need for an understanding of earth processes in environmental management.

The programme was designed for development workers from NGOs, who are not geologists and are involved in field implementation of watershed or water resources development activities. Twenty-four participants from BAIF, other NGOs and government departments attended the programme. The contents of the programme were as given below.

Module 1

- Environmental Processes
- Earth Processes
- Water

Module 2

- Human Interaction with the Environment
- Sanitary Landfills
- Medical Geology
- Land Use Planning

The programme, conducted by Frank Simpson, was held on February 26, 1996 from 9.30 a.m. to 4.00 p.m. at the Hotel Raviraj, Bhandarkar Institute Road, Pune 411 004.

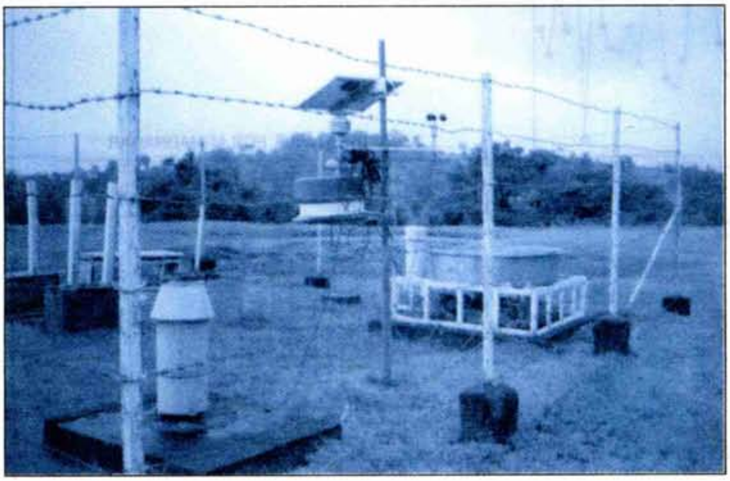
◆◆◆◆

6: HYDROLOGY

6.1 METEOROLOGICAL FACTORS

Rainfall data at the meteorological stations around the area, available from the Meteorological Department, have been compiled to demonstrate trends and for comparison with the data from the stations, established in the project area. The data on temperature, humidity, wind speed and evaporation were collected from meteorological station at Niphad, near Nasik.

6.1.1 TIME SERIES OF ANNUAL RAINFALL



Meteorological station : Manhere village

The fragmentary project records of annual rainfall in and near Akole Taluka from 1840 to the present day in general support the concept of a causative connection between drought and the climatic disturbance known as "El Nino".

El Nino - Southern Oscillation (ENSO) events are large-scale ocean-atmospheric interactions. The tendency for atmospheric surface pressure to be relatively low in the central and south Pacific, when it is relatively high across Australia, SE Asia and the India Ocean, and vice versa, is termed the Southern Oscillation (Philander 1990). The low-pressure condition in the Pacific is accompanied by warming of surface waters in the central and eastern equatorial Pacific and is termed El Nino. So-called "anti-ENSO" events involve cooling of surface waters in the eastern Pacific. ENSO events occur every two to ten years (Whetton and Rutherpord, 1994).

Climatic anomalies, associated with ENSO and anti-ENSO events, are termed teleconnections. ENSO events are associated with reduced rainfall in many parts of the eastern hemisphere. Weak monsoon rainfall in El Nino years frequently gave rise to drought conditions in India in the past two centuries. In general, this view is supported by the time series of annual rainfall from Akole Taluka.

In the past, an important clue about imminent ENSO conditions has been the development of a high-pressure system east of Tahiti, giving rise to strong southeastern trade winds and warming conditions in the western Pacific. However, this sequence of events is far from invariable and much research remains to be done on reliable forecasting mechanisms. Possibly an additional factor is subsea volcanism in the southwestern Pacific.

Annual rainfall data from Ahmednagar (Lat 19005N, Long. 74055'E) Akole (Lat 19033'N - 74001'E) and Nasik (Lat 200N, Long. 73047E) obtained from Indian Meteorological Department (IMD) are presented in graphical form in **Figure 6.1.** They demonstrate the high degree of variability from year to year, which characterises the rainfall in the northern part of Maharashtra.

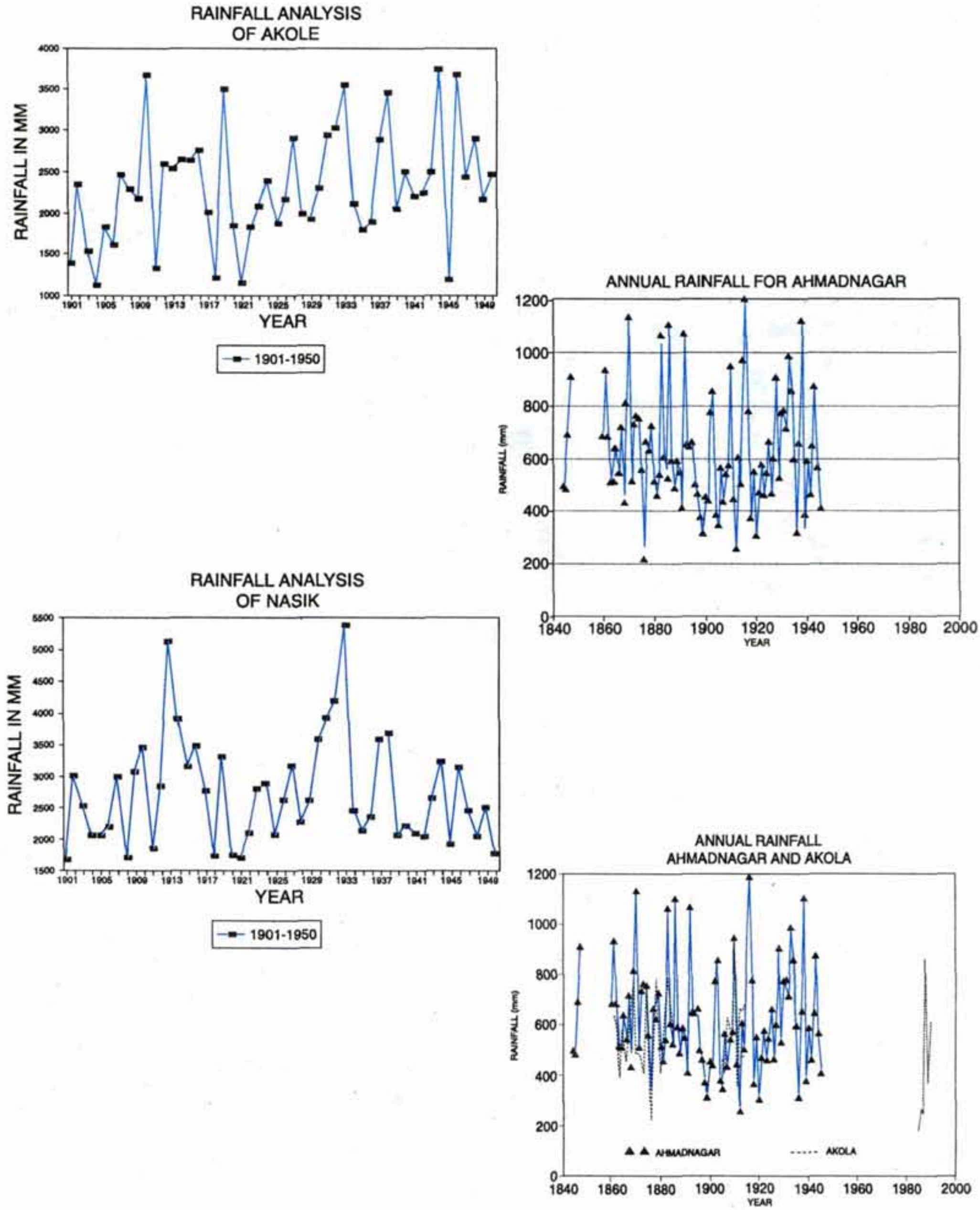


FIG. 6.1 ANNUAL RAINFALL TRENDS OF SURROUNDING AREA.

6.1.2 STUDY OF RAINFALL OF PROJECT AREA

The annual rainfall data from the nearest rainfall stations were collected and presented in tabulated form to compare with the rainfall at Manhere. A large variation is observed over these short distances. See **Table 6.1.**

TABLE 6.1 VARIATION OF RAINFALL

Station	Location from Manhere		Annual Rainfall in mm			
	Distance (km)	Direction	1992	1993	1994	1995
Bhandardara	5.00	S-W		2875	4214	1635.5
Manhere	0.00	-	1548.75	1985.81	2809	1447.73
Titvi	3.75	E	956.1	1294.11	874.3	927.5
Randha	3.25	S-SE		1500	2004	1127.75
Akole	23.00	S-SE			432	350.59

The rainfall data collected from the two raingauge stations established in the project villages of Titvi and Manhere show considerable variation on a day-by-day basis at both locations, even during the wettest month. The details are provided in **Figure 6.2.**

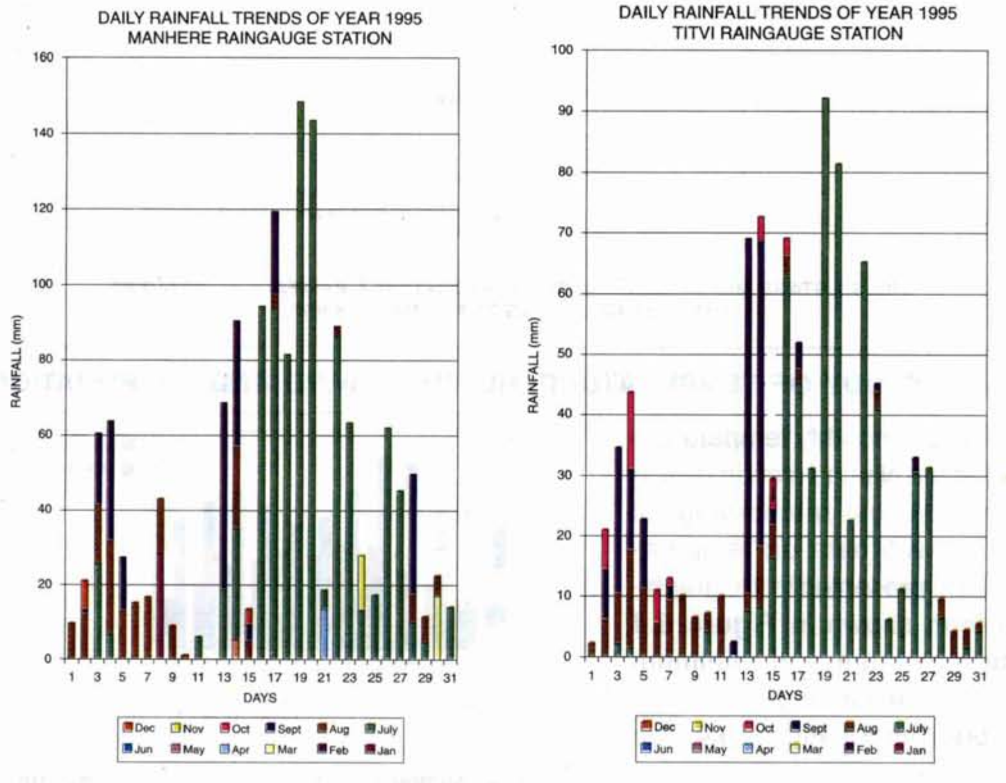


FIG. 6.2 DAILY RAINFALL TRENDS OF PROJECT AREA.

The calculations of runoff are based on the meteorological parameters, i.e. rainfall, evaporation and stage measurement data. The rainfall and evaporation data from automatic meteorological station at Manhere and the rainfall data of Titvi are shown in **Figure 6.3**

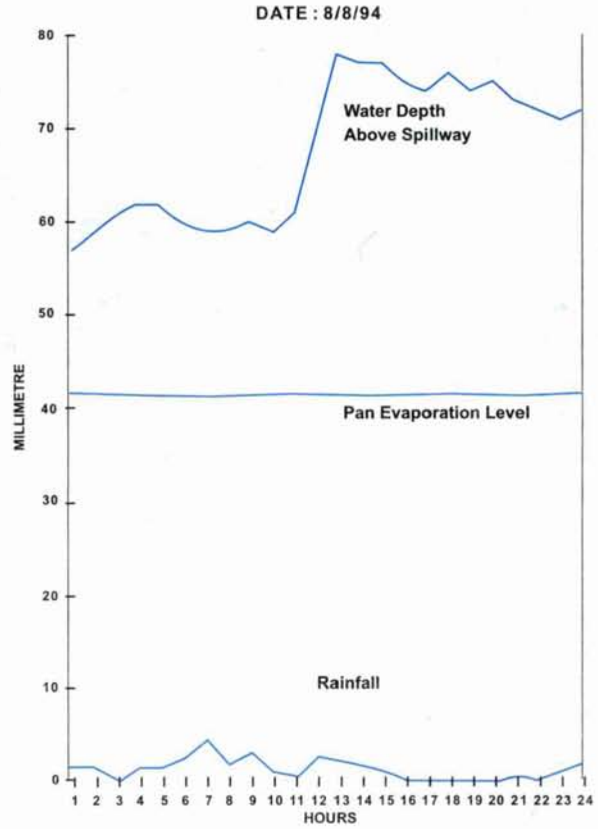


FIG. 6.3 STAGE MEASUREMENTS, PAN EVAPORATION & RAINFALL AT MANHERE
LAT-19 35.42N & LONG 73 47 E DATE : 8/8/94

6.1.3 STUDY OF TEMPERATURE, HUMIDITY, WIND AND EVAPORATION

The mean monthly temperature data at the Niphad station (which is the nearest meteorological station with data on temperature) are presented in the graphical form shown in **Figure 6.4** The maximum and minimum temperatures in degree Celsius are presented in **Figure 6.4**. The graph shows that the maximum

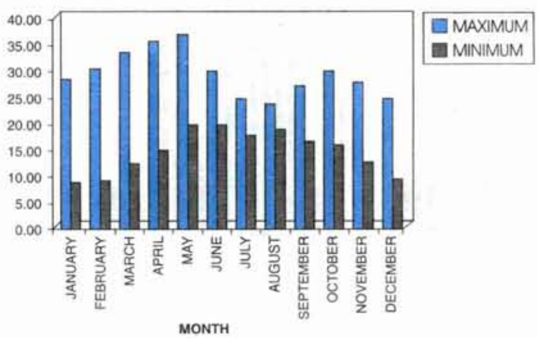


FIG. 6.4 : MEAN MONTHLY MAXIMUM & MINIMUM TEMPERATURE OF NIPHAD (NASHIK) YEAR:- 1984 TO 1986 & 1988 TO 1993 & 1995

day temperature rises up to 38.33^0 C in the month of May, while the minimum night temperature goes down to 7.88^0 C in January.

At the Induri meteorological station, near Nashik, temperatures fall to about 7 degrees Celsius in winter and to as much as 42 degrees Celsius in summer.

The 10 - year data of relative humidity are presented graphically in **Figure 6.5**.

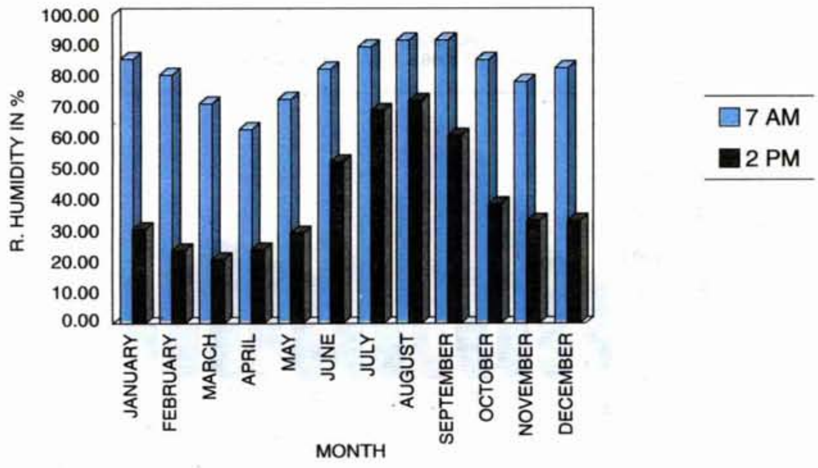


FIG. 6.5 : MEAN MONTHLY RELATIVE HUMIDITY OF NIPHAD (NASHIK)
YEAR :- 1984 TO 1986 & 1988 TO 1993 & 1995

Figure 6.5 shows the values of mean monthly relative humidity (RH) measured at 7 am and 2 p.m. daily. Maximum RH is in the month of September (91.70%) measured at 8 am. The minimum is in the month of March (20.50%) measured at 2 p.m.

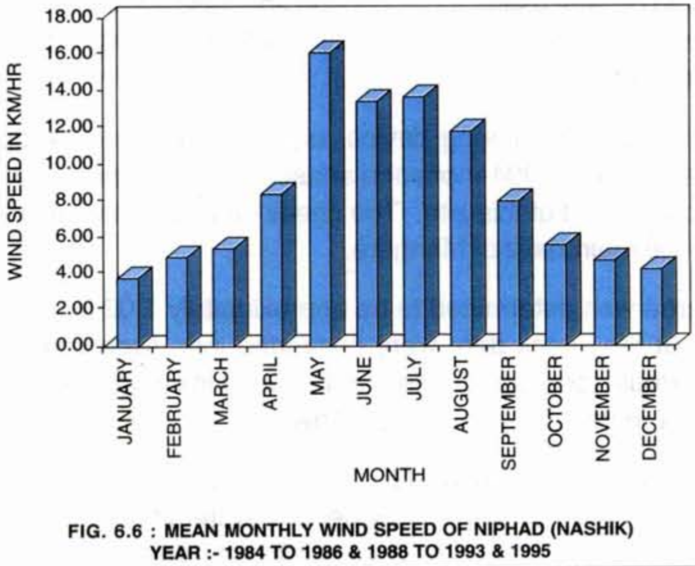


FIG. 6.6 : MEAN MONTHLY WIND SPEED OF NIPHAD (NASHIK)
YEAR :- 1984 TO 1986 & 1988 TO 1993 & 1995

The graph of mean monthly wind speed over a 10 year period is given in **Figure 6.6**. The maximum wind speed is in the month of May (16.05 km per hour) and the minimum in January (3.63 km/hr)

Monthly evaporation in the area is shown in **Figure 6.7**. It shows that the maximum evaporation is in the month of May (12.81mm) and the minimum in the month of December (4.51mm)

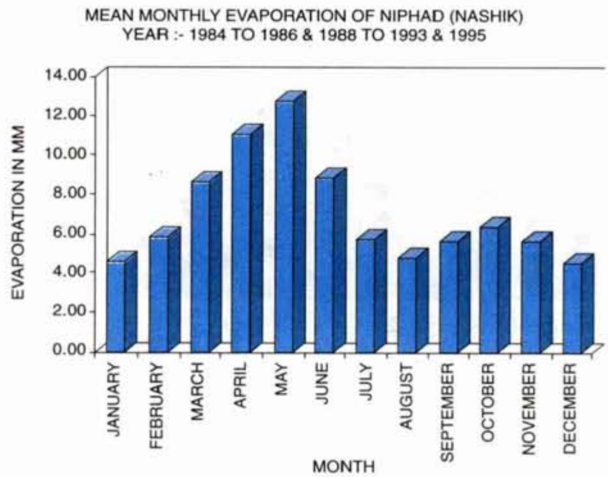


FIG. 6.7 : MEAN MONTHLY EVAPORATION OF NIPHAD (NASHIK)
YEAR :- 1984 TO 1986 & 1988 TO 1993 & 1995

6.2 RUNOFF ANALYSIS

The percentage of rainfall that leaves the study area watersheds as surface runoff is presumed to be very high owing to factors such as extreme precipitation intensities, shallow soils and high drainage densities and relief. Runoff/rainfall ratios for the study areas would be very useful as monitoring and assessment tools. For example, long-term examination of the ratios can help with assessing the effectiveness of catchment treatments.

BAIF installed a stage monitoring device, equipped with a data logger in a sub-basin at Manhere for the 1994 monsoon season. A check dam with a rectangular spillway was constructed at this site. The check dam is located at 19^0 35´.42N and 73^0 47´.00E, in the main *nalla* of Manhere.

The drainage area was determined to be approximately 1.02 sq km. BAIF's stage measurements at the check dam were converted into discharge estimates using the discharge formula for sharp-crested weirs, found in Gregory and Walling (1973). The formula for a rectangular weir is as follows :

$Q = 1.86\ B\ H^{1.5}$ where Q = discharge in cumec
H = head of water in m
B = width of weir crest in m.

The discharge data for the period of July 26, 1994, to Sept. 4, 1994, revealed that approximately 1.248 x 106 m^3 water left the sub-basin over the spillway of the check dam. Based upon the catchment area of 1.02 sq.km. the above volume was converted to a water depth of 1.22 m. Unfortunately a runoff/rainfall ratio could not be calculated for the sub-basin. An equipment problem at the Manhere weather station resulted in a failure to obtain rainfall data for the entire period. There are no rainfall data available for the period of July 31 to Aug. 6. The measured rainfall was 0.82 m. Obviously, even with heavy rains during the seven days of missing data, water outputs from the sub-basin appeared to be greater than or at least equal to precipitation inputs. Analysis for a shorter period of Aug. 7 to Sept. 4 yielded a runoff/rainfall ratio of 1.59. The limited data reveal the problems of examining only a small portion of the rainy season.

Surface outflow from the sub-basin appeared to be equal to or greater than inputs, because of the lag time between water falling on the upper reaches of the drainage area and flowing over the check dam. Runoff / rainfall ratios need to be determined for the entire flow period and for drainage areas of different sizes.

One more masonry weir has been constructed at the outlet of the Titvi micro-watershed to measure the stages for discharge calculations. Length of the structure is 11.0 m, height above GL is 1.25 m, the slope of d/s is 0.5:1 and upstream side vertical.

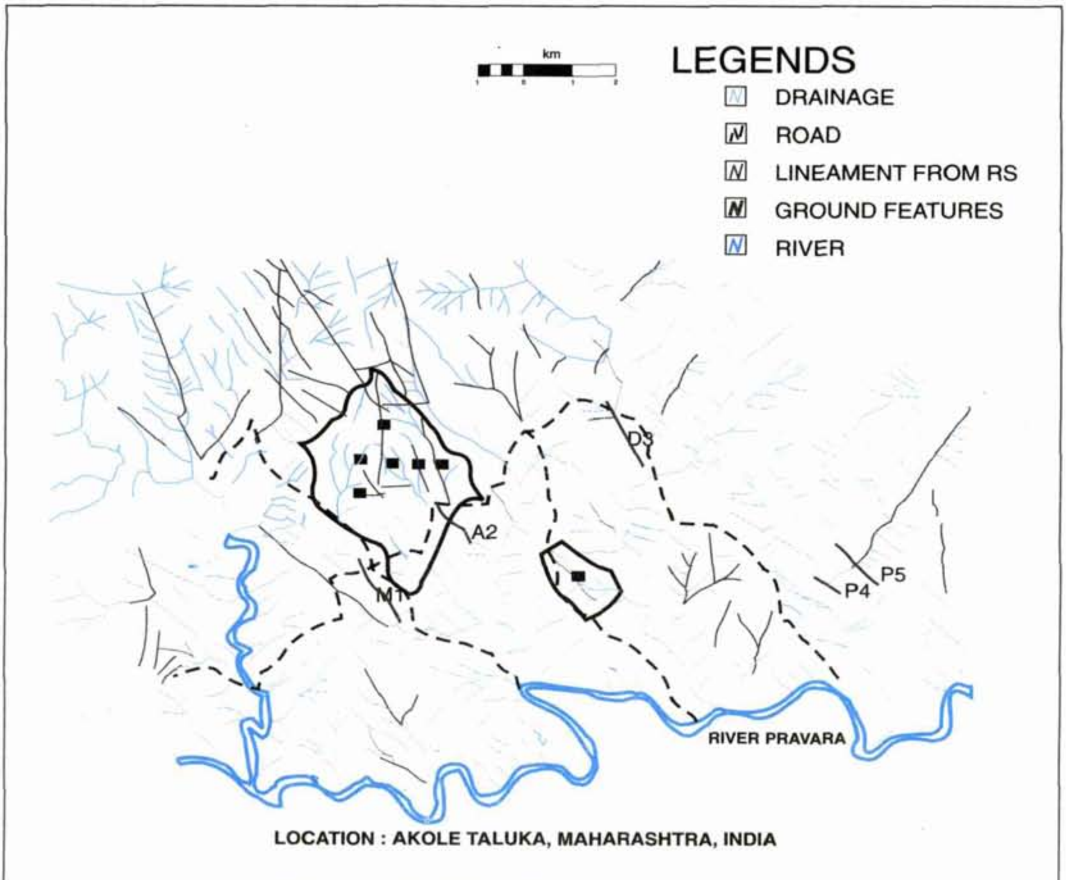
◆◆◆◆

7: GEOLOGY AND GEOHYDROLOGY

7.1 GEOLOGICAL SETTING

In Akole Taluka, the bedrock consists of extensive, generally massive flows of basalt lava, mainly referable to the Kalsubai Subgroup of the Deccan Basalt Group. The regional stratigraphy of the Deccan basalts has been described by *Beane et al.* (1989), Khadri *et al.* (1988), and Subbarao and Hooper (1988). The bedrock geology, shown in **Annexure 2,** is modified after Subbarao and Hooper (1988).

The effects of weathering are widespread in exposures of the lavas and at the contact with superficial deposits. Flow boundaries are exposed at a number of locations. In general, the flows are relatively flat-lying with dips of less than one degree to the south-east prevailing over wide areas. Some significant departures from the horizontal (five degrees or more) were observed locally, for example, to the north of the study area, near Ambevangan. The basalts are commonly amygdaloidal, with cavities (vesicles), plugged by minerals of the zeolite group and calcite. The lavas are commonly fractured and overlain by a soil cover of variable thickness.



LOCATION : AKOLE TALUKA, MAHARASHTRA, INDIA

FIG. 7.1 : LINEAMENT & OTHER GROUND FEATURES

The Earth materials with the best aquifer potential are found in :

- soils, which take the form of silts, silty loams and sandy loams, undergoing a general decrease in grain size and increase in thickness from high to low elevations, beneath a clay-silt surface layer;
- weathered bedrock, with aquifer properties that are transitional between those of the soils and the rocks below, and including spheroidally weathered basalt fragments in different stages of decay; and
- basalt lavas, with vertical separation between consecutive flows at the contacts, notably where flow ridges have been observed on upper surfaces, and transected by open, vertical fractures.

The main, geological factors, controlling ground-water flow in these materials are summarized in **Table 7.1**.

As well, linear ground features were mapped from imagery, obtained from Earth satellites in orbit. These lineaments are interpreted in a number of different ways, which are not mutually exclusive. They were seen to be related to improved aquifer properties in the Earth materials, mentioned above and featured in the water-resource management strategy, developed during the project (**Fig.7.2**).

7.2 SUPERFICIAL DEPOSITS

7.2.1 SOIL TEXTURE

The soil classification available with the GOI records show that the soils are sandy loams and silty loams. BAIF tested ten samples, collected in 1994 from the adjacent valley in Ambevangan village on the east side. Nine of these were silt loams, while

TABLE 7.1 MAIN GEOLOGICAL FACTORS CONTROLLING GROUND-WATER FLOW IN AKOLE TALUKA, MAHARASHTRA : MEGASCOPIC FEATURES

Feature	Scale	Recognition	Remarks
MEGASCOPIC FEATURES			
Regional fracture systems	$>10^2$km	satellite imagery, resistivity, VLF-EM	NE,NW, Etrends, deep pervasive fractures probably related to plate interaction
Local fracture	$<10^2$km	satellite imagery, resistivity, VLF-EM	NE,NW,N trends including deep pervasive fractures, best ground definition upslope
Basalt dikes	range as for fracture system	satellite imagery, resistivity, VLF-EM	Trends as for fracture systems, definition in upslope locations reinforce by weathering, recognition assisted by joints normal to margins
Alluvial valley fill	related to stream hierarchy	satellite imagery, resistivity, test drilling	Linear bodies with all above trends;channel (-fill geometry thickening downslope, fans and aprons in main valleys; blankets other features

LINEAMENTS, DRAINAGE AND WATER CONSERVATION

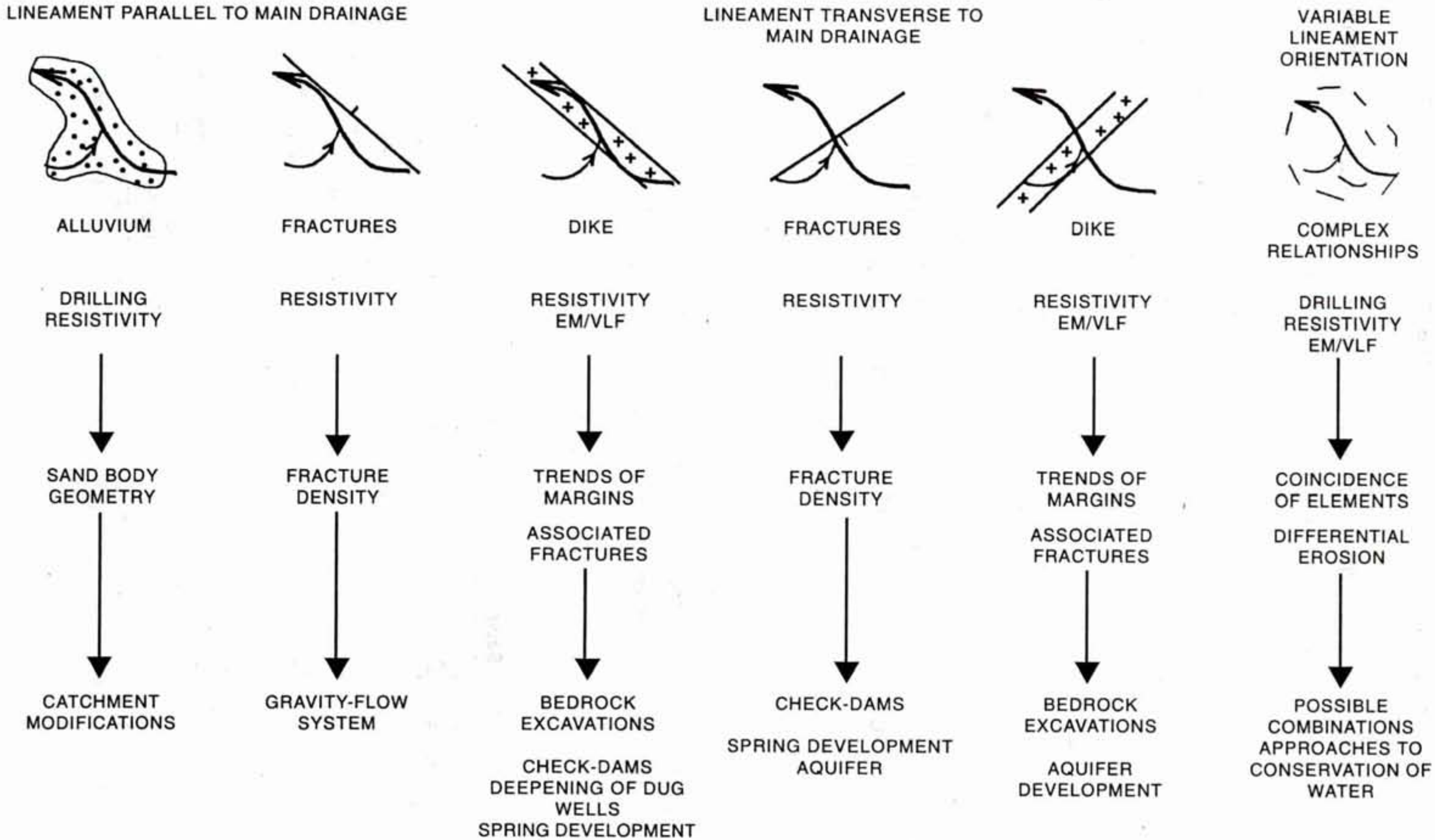


FIG. 7.2 : LINEAMENTS, DRAINAGE AND WATER CONSERVATION

one was a sandy loam. To establish that silt loams are the dominant variety in the conjuctive use study areas, twelve soil samples were analysed at the University of Windsor in June, 1995. These were collected from various locations and depths in an attempt to recognise any systematic differences that may exist in soil textures within the study area. Nine of the samples were from nalla paddy fields and three from hillside terraces. **Annexure 3** provides details on precise location and classification. **Annexure 4** shows sample locations. The samples were analysed using the hydrometer method outlined by *Das, B. M.* (1998). The coarse fractions were determined by wet sieving the samples through a #200 sieve (75m) and oven drying the retained material.

The samples ranged between silt and loamy sand. The soils tend to be coarser at higher levels in the watershed and closer to the weathered rock. There are exceptions to this, as demonstrated by the two samples Amb-TENS (*nalla* paddy) and Amb-IP (hillside terrace). These two samples were separated by a vertical distance of 20-30 m, but are very similar in texture. Five of the samples were from the area upvalley from the developed roadside spring (*kelly* spring) in Ambevangan. This spring is relied on heavily for potable water supply and it is desirable to increase the quantity of water available to this particular source. Typically, the source dries up in May. The weathered basalt below the soil cover is the suspected aquifer for the spring and therefore must be the focus for recharge. Buried infiltration pits (stone-filled) were introduced in the paddy field immediately above the spring, but the usefulness of these structures is in doubt, partly because of the silt loam covering the pits. All the samples collected in the area were silt loam or silt. The amount of recharge water moving through these soils to the weathered rock is minimal. Local landowners are against any structures that reduce paddy field area or interfere with their field work. If acceptable, narrow recharge trenches allowing direct movement of surface water to the weathered basalt may increase the water supply at this spring.

Three samples were selected down the main *nalla* of Manhere and they reveal a change of coarser to finer material in a downvalley direction. The soils of the valley head areas tend to be shallower, but appear to be more conductive than the paddy soils in valley bottoms. Unfortunately, in all likelihood, water entering the watershed at these higher locations flows back out to the surface a short distance downvalley, above impermeable basalt flows.

It is interesting to note that the coarsest material found was extracted from the soil / weathered basalt interface (Titvi-3B). This was the only sample collected at the interface.

7.2.2 PERMEABILITY TESTS

Field-saturated hydraulic conductivities (Kfs) of the study area field soils were estimated using the constant-head well method outlined by Reynolds and Elrick (1986, 1987) and Elrick and Reynolds (1992). The measurements were made using a field permeameter constructed by technical support staff at the University of Windsor. The permeameter was designed to be used in an auger hole with a minimum diameter of 6.0 cm and a maximum depth of 5 m. The measurements performed during this field work season were completed in 9.0 cm diameter auger holes of various depths. Kfs calculations were based on a = 4 and C value associated with Guelph loam.

Studies In The Titvi Area

Permeameter tests were conducted in three separate fields. **Annexure 5** provides details on permeameter tests. A 1x1x1 m size pit was excavated in the first test field (Titvi-1), from which 10 soil core samples were collected. Three additional soil samples were taken from the auger holes in the third field (Titvi-3) and were examined. **Annexure 3** provides the soil moisture, porosity and bulk density for all soil samples collected. Eleven water samples (30 ml) were collected and 13 measurements of electrical conductivity were taken. The details are provided in **Annexure 6.** Instantaneous rivulet discharge (2.25 L/s) was estimated on Dec. 8/93 approximately 100 m down-valley from the last paddy field in the study area. No monitoring wells or tensiometers were installed in the area.

Studies In The Manhere / Ambevangan Area

Permeameter tests were conducted in four separate fields (**Annexure 5**). Six soil samples were collected from auger holes in the four fields. Ten water samples (30 ml) were collected and 14 measurements of electrical conductivity were taken (**Annexure 6**). Instantaneous rivulet discharge (7.99 L/s) was estimated on Dec.11/93 in the paddy field directly above the *kelly* spring in Ambevangan. Three groundwater monitoring wells (Amb wl, Amb w2 and Man w1) were installed as deep as possible in pockets of saturated soil.

Several more sites were identified for well installation. A tensiometer cluster was installed in a representative paddy field (third above the *kelly* spring) in the eastern *nalla* at Ambevangan. There are four tensiometers in the cluster, at depths of 60, 90, 120 and 150 cm. Protective barriers have been arranged for the tensiometers and monitoring well sites. The tensiometer readings and readings of the water levels in the monitoring wells are being recorded regularly.

Three fields of Ambevangan had pockets of saturated soil and monitoring wells were installed in two of these fields. A monitoring well was installed in a saturated area of the *nalla*, immediately west of the Manhere community well (at the road). Several more fields at Manhere appeared to be saturated but have not yet been investigated. It is planned to map the areas with saturated, soil during the wet and dry seasons. These areas are worth detailed study, because they may represent : (i) successful dugwell sites or (ii) if a well already exists, an opportunity to increase water availability by delaying / minimising subsurface losses with a subsurface barrier. Hanson and Nilsson (1986) state that simple water table monitoring can help identify the natural flow pattern, which is necessary for site assessment.

In a few locations, rivulet waters were observed emerging from the bottom of paddy field bunds. At two such sites, test holes were augered in the paddy fields immediately above the emergence points but weathered rock terminated augering before detection of the water table. This suggests that the weathered basalt has the capability of storing and releasing significant amounts of water. No measurements of the effective porosity or specific yield of the weathered materials in the study area were attempted, but others (e.g. *Deolankar,* 1980; Chandrashekhar *et al.*, 1976) have reported specific yields of weathered Deccan basalts in the range of 2-7%. An approach for determining the transmissivity of this material would be to perform pump tests (e.g. Barker and Herbert ,1989) with the existing dug wells that partially or wholly penetrate the weathered basalt. The hydraulic conductivity of the weathered basalts remains unknown, because of the difficulty with hand auguring into the material. Deolankar and Kulkarni (1985) investigated the Deccan basalts of Maharashtra using pump tests from dugwells and reported permeabilities of 2 to 5 m/day for weathered amygdaloidal basalts and 0.1 to 1 m/day for jointed basalts. Limaye and Limaye (1985) state that the Deccan Traps have permeability, which is related to the presence of vesicular flows, permeable flow junctions, intertrappean beds, red boles, etc., and the permeability of the near surface (< 100 m) basalts ranges between 1.2×10^{-8} m/s and 5.8×10^{-7} m/s (.001 to .05 m/day).

The majority of the hand-dug wells and blast holes in the study area penetrate the weathered basalts, but it seems that only a few produce water during the late summer months. It may be possible to increase the yields from some of these dug wells by the conversion to collector wells. Ball and Herbert (1992) converted 32 dug wells in Sri Lanka and found that the yields doubled on average.

The electrical conductivity of the tested waters (**Annexure 6**) reveal that there is little variation in the electrical conductance of bored well, dugwell and surface waters of the study areas. All samples fall into the range of 170-315 μS/cm and are in agreement with the values reported in association with the reconnaissance survey of May, 1992. No anomalies were observed.

The hydraulic conductivities (Kfs) expected for soil types of the area range between 10^{-8} and 10^{-6} m/s. Field permeameter tests for both 1993 and 1995 fall within this range. **Annexure 5** give details about the 1993 and 1995 field permeameter tests. **Annexure 4** shows the locations of the 1993 and 1995 permeameter tests.

Four of the tests were at terraced hillside areas, three at non-terraced hillside locations and two in weathered basalt (*murum*). Hand augering was difficult in two shallow holes which were excavated using sharpened metal bars and probes. Overall, the hydraulic conductivities were greater for the 1995 tests compared to the results of 1993. The four terraced hillside conductivities were in the 10^{-6} m/s range, the fastest of all the conductivities measured (1993 included). This is interesting because the soil texture of samples taken at the terraced hillsides were not different from the other soils tested. Both the hillside samples were silt loams. The weathered basalt tests suggest that the weathered rocks are not as conductive as the terraced hillside soils, but are more conductive than the soils of the paddy fields in the main nallas. Heterogeneity of the weathered basalts, related to the extent of weathering, will modify this relationship from place to place.

Discussions On Permeability Test Results

The results shown in **Annexure 5** reveal that the soils in the main nalla paddy fields of the study areas are of very low permeability (10^{-8} m/s). The soil texture is very fine (silt/clay) and the soils become mouldable, when moist. Surface cracking (up to 1 cm wide) is evident, as the fields dry out. Soil texture remains fairly uniform with depth down to the weathered rock interface. Soils of higher permeability (10^{-6} m/s) appear to exist in upland areas, but there is not yet sufficient information to determine the extent to which these conditions prevail. The soil porosity ranges from 39-53 (% soil volume), but the sample with the lowest porosity (39 %) represents the soil weathered rock interface. This data indicate that the soils of the study area are capable of storing significant amounts of water but are of low permeability, because of their very fine texture. A low specific yield (e.g. 1-2%) is suspected for these soils and this is not favourable for the subsurface storage of water. Hanson and Nilsson (1986) state that the storage media should contain significant amounts of sands and / or gravels and should be underlain by low-permeability material. These researchers point out that it is possible to use an aquifer of low permeability, but additional collection systems (e.g. slotted pipes normal to the subsurface dam) are required to increase water availability. This assumes that natural subsurface flow is responsible for the loss of groundwater at the site in question.

Saturated soil conditions were not common. No saturated soils were found in Titvi and only a few saturated pockets were observed in the Manhere/Ambevangan study area. The majority of dugwells and blast holes were full of water, but in most cases the adjacent soils were not saturated. With a few exceptions, the soils in the main nallas are of such low permeability that rivulet water simply flows across the top of the unsaturated fields with very little infiltration. Water retained in surface depressions on some of the field is lost by evaporation.

7.2.3 SURFACE INFILTRATION TESTS

Estimates of surface infiltration rates complement the field permeameter data. which yield estimates of the average (vertical and horizontal), saturated hydraulic conductivities within the matrix. The surface tests are required to provide information on how fast one can expect ponded water to penetrate the various surfaces common in the study area. **Annexure 7** gives details about the surface infiltration tests. **Annexure 4** shows the locations of the surface infiltration tests. Five locations were tested for infiltration capacities. Two were soil surfaces (one hillside and one paddy), two were at the weathered rock (*murum*) surface and the remaining site was carved into weathered basalt. All sides of the test holes were lined with plastic to minimize lateral water loss, except for the hole excavated into the weathered basalt. This would not completely prevent lateral movement of water, so the resulting infiltration rates should be considered as maximum values. Water was added to each test hole before measurements began in order to saturate the matrix. The quantity of water added varied from about 1 L to 20 L. At the Man-chan-m site, observation holes were created at 20 cm and 60 cm below the test hole. Our infiltration tests indicated that the rates of movement though the unsaturated weathered rock were not uniform. The first water at the 20 cm level appeared four hours (1.4×10^{-5} m/s) after initial water addition, but was not evident at the deeper hole, until approximately the 42-hour mark (4.0×10^{-6} m/s).

This weathered basalt variability was supported by another test nearby, where infiltrating water travelled a distance of 90 cm in approximately six hours (4.2×10^{-5} m/s) Owing to the swelling properties of the soils and the fine material in the joints of the weathered rock and/or less permeable horizons at depth, the infiltration rates decreased with time.

Generally, all the infiltration rates were in the lower 10^{-5} m/s range. The slowest of the surface tests (Man-hill-s) was still approximately double the fastest permeameter result and these measurements were taken in close proximity. This suggests that the near-surface layers are more conductive and/or the vertical hydraulic conductivity is greater than the horizontal hydraulic conductivity. The presence of macropores (e.g. root channels) naturally will increase the rate of near-surface water movement. Overall, the data indicate that surface water will move quickly into the near-surface zone, but then soon reaches more compact or less permeable layers. Under these conditions, the upper permeable horizons may become saturated and cause partial area overland flow, even though the matrix below is unsaturated. This in turn implies that the soils of the study area watershed may never reach full saturation during the monsoon season and that shallow ground water recharge only occurs at isolated locations.

7.2.4 FACTORS CONTROLLING FLUID FLOW

The main, geological factors that exert an influence on the movement and storage of ground water in the soils and weathered bedrock are summarized in **Table 7.2**. The following, additional comments should be considered in future expansions of the existing water-resource management programme :

- The more sandy soils are found in the upslope terminations of valleys, both on the uppermost terraces and in the valley sides. In general, these give way to finer-grained soils and mixed associations at lower elevations. However, a thin veneer of clay and fine silt is spread by sheet (overland) flow of monsoon runoff at all terrace levels and adjacent lower reaches of the valley sides. The surface layer has the effect of reducing infiltration by meteoric waters. This can be put to use, where water is being directed toward infiltration trenches from a catchment, such as a road surface.
- Macropores are open cavities in soil, formed below ground level, as a result of combination of biological, chemical, and physical factors. The largest

TABLE 7.2 Main Geological Factors Controlling Ground-Water Flow In Akole Taluka, Maharashtra : Macroscopic and Microscopic Features

Earth materials	Features	Remarks
MACROSCOPIC AND MICROSCOPIC FEATURES (1)		
Soils	Interstices	Interstices Intergranular porosity increasingly subordinate to microporosity at low elevations.
	Macropores	Product of complex and variable interaction of physical, chemical and biological factors.
Weathered basalts	Interstices	Clay microporosity around weathered spheroids.
	Spheroids	Best porosity at sites of fragmentation/separation of concentric "onion skin".
	Fractures	Largely observed as clay alteration products of weathering.
MACROSCOPIC AND MICROSCOPIC FEATURES (2)		
Flow top	Flow-ridged	Anisotropy of permeability parallel to direction of lava movement.
Intraflow (Basalt lavas)	Stratification	Intercrystal porosity may contribute toseepages; layering mainly defined by vesicles and mineral banding.
	Vesicles	Lining and occlusion by late-stage minerals notably zeolite is wide pread
	Tunnels	Various irregular, cylindrical cavities up to a few dm wide.
	Fractures	Include joints and vein systems oriented parallel to local features.
Flow base	Flow folds	Undulating interface/stratification at base of flow.
MACROSCOPIC AND MICROSCOPIC FEATURES (3)		
Pyroclastics	Porous clasts	Intraparticle porosity of sporadic distribution.
	Interstices	Intergranular porosity best developed in these materials
	Fractures	As in basalt lavas.
Basalt dikes	Fractures	Joints oriented normal to dyke margin.
Interflow soil	Interstices	Intergranular porosity reduced as a result of heat-induced alteration.
	Fractures	Extensive small-scale fractures with mineral lining

macropores, observed in study area, were animal burrows, 2-4 dm in length. Macropores can have a strong influence upon the rate of movement of ground water. Closely spaced macropores in loose soil, such as those, associated with the burrowing activities of land crabs, can reduce soil strength and degree of compactness. In some parts of the study area, this has given rise to localized erosion and related gully formation.

The weathered bedrock marks a chemical and physical transition between the volcanic bedrock and the soils above. Spherical masses of essentially unaltered lava are surrounded by concentric layers of weathered material, with the degree of transformation from the original material becoming more pronounced outwards. These bodies are set in a matrix of fine-grained weathering products. The proportion of this increases upwards. Seepages of ground water from the weathered bedrock were frequently observed in dug wells, notably above the vertical fractures in the bedrock.

7.3 LAVAS

7.3.1 GENERAL FEATURES

The lavas, exposed in the study area, are for the most part massive, tholeiitic basalts, referable to the Thakurvadi Formation of the Kalsubai Subgroup. Lava flows in the area appear to be mainly compound in nature, consisting of amalgamated, successive flow units. Internal structures within flows are generally restricted to vesicles, filled with zeolite minerals and occurring in crude, planar arrangements, seen at several locations to be parallel and subparallel to the flow boundaries.

In the account that follows, the brief comments on regional setting of the lithostratigraphic subdivisions of the Deccan Basalt Group are based mainly on observations over a wider area by Beane *et al.* 1986), Deshmukh and Seghal (1988), Khadri *et al.* (1988), and Subbarao and Hooper (1988). The remarks on lava petrology and geochemistry in the study area draw upon the M.Sc research of Agarwal (1994), carried out under the supervision of Smith and Simpson. The summary of zeolite mineralogy is based on the B.Sc. research of MacDonald (1994), supervised by Blackburn.

The basalts of the study area belong to the Middle Unit of the Thakurvadi Formation (**Annexure 2**). The Lower Unit occurs in the valley of the Pravara River, to the south of Titvi and farther east along the river valley. The mountains to the west (Kalsubai) and north of the study area are made up of basalts of the Upper Unit of the Thakurvadi Formation, overlain by the Bhimashanker Formation, the highest subdivision of the Kalsubai Subgroup. The summits of the mountains are in the youngest, lithostratigraphic unit, seen in the vicinity of the study area, the Khandala Formation of the Lonavala Subgroup.

7.3.2 LAVA PETROLOGY AND GEOCHEMISTRY

An attempt was made to integrate petrologic and geochemical data on the lavas, as a contribution toward relating local bedrock geology to the regional stratigraphy, developed by other workers. From the beginning of the joint work, both teams took the view that the water-resource management strategy, arising out of the project, would be transferable to other parts of the Deccan Trap region. However, the massive nature of the lava flows in the study area suggested that the bedrock geology of other parts of the Deccan Trap region is likely to be much more amenable to water-resource development.

Accordingly, 47 samples from parts of the lava pile, penetrated by dug wells and blast holes and from a small number of widely scattered roadcuts, were examined under the petrographic microscope and described in detail. Major element analysis was carried out using standard X-ray fluorescence (XRF) methods. Trace elements were investigated, by means of an inductively coupled plasma-mass spectrometer (ICP-MS).

In the study area, the lavas are light grey to greenish grey, aphyric and porphyritic to microphyric, and fine-to medium-grained, massive basalts. The rocks are commonly amygdaloidal, with the amygdules occupied completely and in part by zeolites and other cavity-filling minerals, Vesicular (porous) lavas are relatively scarce. No consistent pattern of vesicle distribution and infilling was recognized in the field.

In thin section, the lavas generally are seen as fine - to medium-grained olivine and olivine-clinopyroxene basalts with phenocrysts making up 2 to 15% of the rock. The olivine phenocrysts show extensive alteration and range from 0.5 to 2.5 mm in diameter. The phenocrysts of clinopyroxene are commonly smaller in size (1 to 2 mm) and are unaltered. Plagioclase phenocrysts typically range from 2 to 4 mm in diameter. Less commonly, phenocrysts of magnetite occur, ranging in size from 0.5 to 1 mm.

The groundmass exhibits textures that are intersertal through intergranular to sub-ophitic and ophitic. Typically, it comprises 30-35% plagioclase, 25-35% clinopyroxene, 10-15% glass, 2-4% iron oxides (magnetite and ilmenite) and 2-3% clay. Partially devitrified, cryptocrystalline glass occurs in places. There is also sporadic alteration of groundmass to chlorite and possibly smectite.

Two petrographically distinctive suites are recognized among the lavas of the Middle Unit of the Thakurvadi Formation, on the basis of phenocrysts content:

- an association of olivine (1-2% of the rock), plagioclase (10-12%), and clinopyroxene (3-5%) phenocrysts (suite 1); and
- an association of olivine (2-3%), plagioclase (10-15%), clinopyroxene (2-4%), and magnetite (2-3%) phenocrysts (suite 2).

Early-formed phenocrysts tend to the enveloped, wholly or in part by those, which crystallized later. Olivine was the first mineral to crystallize as phenocrysts, followed by plagioclase, clinopyroxene, and magnetite, in that order, but with overlapping relations between all minerals in the crystallization sequence. The first mineral to undergo subsequent, chemical alteration was olivine, which gave way to iddingsite. Other phenocrysts and groundmass material show different degrees of replacement by chlorite, limonite, and other alteration products.

The analyses of major elements showed that the compositions of suite-2 lavas lie within the range in chemistry of lavas, belonging to suite 1. Samples of suite-1 lavas contained relatively large ranges in amount of Zr (107- 131 ppm), SiO_2 (47.13-52.49 wt. %), and CaO (7.23-11.03 wt. %). More limited ranges characterize Fe_20_3 (10.47-12.34 wt. %), TiO_2 (1.59-1.76 wt. %), P_2O_5 (0.14-0.17 wt.%), and MnO (0.13-0.22 wt. %) Samples of suite-2 lavas contained relatively large ranges in amount for Zr (111-138 ppm), SiO_2 (47.25-52.37 wt. %), CaO (7.01-11.29 wt. %), and P_20_5 (0.11-0.18 wt. %) and more limited ranges for the other elements.

The analyses of trace elements also showed that the compositional range of suite-2 lavas is within the range, determined for the lavas of suite 1. Samples of suite-1 lavas gave relatively large ranges for V (300-375 ppm), Ni (84-298 ppm), and Cu (99-227 ppm). More limited ranges were observed for Li (5-14 ppm), Co (42-55 ppm), Y (22-38 ppm), Nb (7-12 ppm), Yb (0.6-2 ppm), La (16-30 ppm) Ce (16-37 ppm), Pb (2-7 ppm), and Th (2-5 ppm). Samples of suite-2 lavas showed relatively large ranges for V (299-378 ppm), Ni (83-132 ppm), and Cu (100-153 ppm). More limited ranges were observed for Li (3-9 ppm), Co (43-58 ppm), Y (24-28 ppm), Nb (6-11 ppm), Yb (1-2 ppm), La (16-20 ppm), and Ce (21-30 ppm). The elements showing overlap between the two suites are V, Cu, Y, La and Ce. Partial overlap exists for most of the other trace elements.

7.3.3 ZEOLITES

Zeolites and other minerals (calcite, celadonite) that contribute to the filling of cavities in the basalts have several modes of occurrence :

- lining and filling material of vesicles (open) and amygdules (plugged);
- sporadic distribution along intraflow partings, oriented parallel and subparallel to flow boundaries;
- lining material on the surfaces of joints, frequently oriented normal to flow boundaries; and
- local, surface concentrations, associated with fractures in depth, plotted as lineaments from satellite imagery.

Thus, these minerals contribute to the general reduction of the permeability of the lava pile. However, the local surface occurrences of zeolite crystals in soils should be assessed as possible indicators of deep fractures that might serve as conduits for ground water.

Amygdules and partly infilled vesicles are frequently spherical, subspherical and ovoidal, They commonly form dense concentrations at particular levels in the flows and commonly give rise to a crudely defined layering, parallel and subparallel to the flow boundaries. The apparent, long diameters range from about 1 mm to several cm and show a preferred orientation, in the plane of the crude layering. Amygdules and vesicles do not appear to form a continuous network in the lavas.

Pipe amygdules and partly filled vesicles are more or less vertical. They range in diameter from several mm to 2 cm or more and are commonly several cm in length. The pipelike features occur as aggregates, toward the base of a flow or individual flow unit in a compound flow.

Detailed descriptions of 45 hand specimens and 27 thin sections of amygdaloidal basalts were made in the laboratory. These were combined with determinations of chemical composition, obtained by microprobe analysis, carried out for 56 sites on seven samples, selected for the wide variety of zeolite minerals present. Microprobe identification of individual zeolite minerals involved matching data on the main cation present with the Si/Al ratio, which is fixed for each zeolite species. As well, the petrographic data on each zeolite provided a useful frame of reference in interpretation of the chemical data.

The amygdules are occupied by cavity-rimming celadonite, calcite, and the zeolite minerals heulandite, stilbite, epistilbite, mordenite and scolecite, All of the zeolites are calcium-rich and indicative of relatively low temperatures of formation. Heulandite, epistilbite, and scolecite are common and widely distributed throughout the middle part of the Thakurvadi Formation in the study area. Mordenite and stilbite are rare.

Amygdule infillings typically exhibit zonation from the walls of the former cavity to the centre. Minerals are finely crystalline and, in some cases acicular, at the walls and expand to larger euhedra at the amygdule centre. Scolecite commonly forms a rim around heulandite and less frequently, mordenite was also seen to rim heulandite. The sequence of minerals from rim to centre reflects the order of crystallization.

7.3.4 FACTORS CONTROLLING FLUID FLOW

The main, geological factors with a bearing on the movement and storage of ground water in the basalt lavas and associated rocks of the Deccan Trap are listed in **Table.7.2**. The list includes a few features, reported from other parts of Ahmednager District, but as yet unrecognized in the small and widely scattered exposures of volcanics, examined in the study area. The following, additional comments are made to promote expanded development of water resources in the future :

- Flow boundaries were relatively rare in exposures. Their occurrence was confined to a few road cuts. Flow ridges were seen on scarce tops of flows. On modern lava flows, they are arcuate, with the leading edges oriented more or less normal to the direction of lava movement. The ridged, upper surfaces of flows can be expected to localize the migration of ground water. Locally, even minor variations in dip will influence the direction of water movement. Flow folds were not seen in the study area to date, but may be revealed by future excavations into bedrock.

- Repeated, vertical variations in amygdule concentration were taken to indicate a compound nature for the flows observed. The crude layering, defined by increased concentrations of amygdules, was regarded as unlikely to exert a significant influence on ground water migration. Plugging of vesicles by zeolites and other minerals, the general absence of any, significant interconnection between vesicles, and the tight nature of the lavas ensure that the movement of ground water in the lava pile is largely restricted to features, which interrupt the vertical and lateral continuity of flows.

- Lava tubes and related, tunnel-like features have not been widely reported from the Deccan Trap region. Irregular, broadly cylindrical openings were observed at a few locations, notably in the hillside, to the north of Ambevangan. These range in width from a few dm to more than 2 m and extend for several metres into the hillside. The tunnels are elongated approximately parallel to the boundaries of flows. Future excavations into bedrock may reveal more extensive tunnel forms in the lavas. Probably, these would mark preferred, local directions (anisotropy) of movement of ground water.

- Associated rock types that interrupt the vertical continuity of the basalt lavas over a wide area in other parts of the Deccan Trap region include pyroclastic deposits, in the form of ash accumulations, and ancient soils. These occur between flows at some locations. They exhibit distinctive mineral assemblages ("red bole") that reflect thermal alteration during emplacement of the flow above. The interflow, sedimentary rocks are transected by closely spaced, interconnected fractures. Accordingly, these rocks have major aquifer potential and could make a significant contribution to water supply.

- The lateral continuity of the impermeable basalt flows is broken by fractures and by relatively scarce basalt dikes. Vertical and subvertical joints are relatively common in the better exposures of lavas, to the north and north-west of the study area. More extensive vertical fractures occur as isolated features and in groups. Springs and seepages are frequently localized in the weathered bedrock in the vicinity of the larger fractures. Slow seepage of ground water also takes place at the margins of the scarce basalt dikes that transect the lavas.

7.4 LINEAMENTS

7.4.1 PROCEDURE

The Canadian Project Team brought to the joint activities with BAIF experience in the use of linear ground features (lineaments), recognized on imagery from Earth satellites, to identify deep, pervasive fractures, as part of a strategy for petroleum exploration and development in the Western Interior of North America. It was believed that a similar approach to fracture analysis in Akole Taluka would yield valuable information on the movement of ground water and its relationship to deep-seated controls of surface drainage.

The Indian Project Team collaborated with the Government of India's Space Application Centre, Ahmedabad, in the use of remote sensing during the early stages of project planning. Team members worked closely with SAC in the interpretation and presentation of land-surface data for Akole Taluka, obtained from satellite imagery. BAIF also obtained valuable input from the Maharashtra Remote Sensing Application Centre, Nagpur, on ground features in Akole Taluka, interpreted from analysis of satellite imagery and air photographs.

Outputs from these interactions included maps of the main lineaments in Akole Taluka, on scales of 1:25,000 and 1:50,000. In the field, precise locations of sampling sites were signalled from Earth satellites to a hand-held Global Positioning System (Magellan GPS NAV 5000 PRO). The tribal and rural people shared their knowledge of local sites of ground-water discharge and botanical indicators of shallow ground water. The use of Geographic Information Systems (GIS) by the staff of BAIF's Information Research Centre in Pune greatly facilitated comparison of these data sets with information on drainage and topography.

The main, possible interpretations of lineaments in Akole Taluka were recognized early in the project (**Table 7.3**). All were judged as having major potential to control the flow of ground water on a megascopic scale, varying from local to regional, and to influence hydraulic continuity between subsurface and surface waters. The lineament map was overlain on the bedrock geology (**Annexure 2**) to facilitate investigations in the field.

TABLE 7.3 IDENTIFICATION OF LINEAMENTS

Lineament Identification No.	Description
M-1	Not apparent in the field. Thick soil cover. May be representing a weak, fracture zone. Direction : NW-SE.
M-2	Marked E-W, on a fairly large plateau which supports a lot of vegetation. The linement could actually represent a line of ridge and trees running in the east west directions. There is no direct evidence of either a fracture or a dyke.
M-3	These represent the crest of a ridge running
M-4	N-S. The crest supports some vegetation. No evidence of major regional fracture or joint patterns.
M-5	No direct evidence of fracture or jointing in the rock. A part of it concides with the NW-SE regional trend.
M-6	No surface expression due to the thickness of soil cover.

Contd....

A-7	Not apparent in the fields to the north of the road leading to Ambevangan. However, the fracture system or fracture zone is very clear to the S-SE of Wadi and south of the causeway on the road to Ambevangan. At this location, the fracture zone is evident in the stream beds in the form of fractures trending N-NW - S-SE. The springs and seeps are lineament has not been marked on the lineament map but can be traced further downstream.
T-8	Titvi watershed - No evidence of a fracture or dyke. The lineament is practically parallel to the main drainage direction. The lineament seems to represent portions (in the higherreaches) of stream segments.

BAIF carried out a limited resistivity survey at and near selected dug wells, sited on systems of vertical fractures, coinciding with lineaments. As well, many of the hydrogeological field studies and a radon survey were designed to test hypotheses on the possible control of ground-water movement by fracture systems, associated with lineaments.

7.4.2 INTERPRETATION OF LINEAMENTS

The main interpretations of the lineaments, mapped in near Akole Taluka from satellite imagery, are included in **Table 7.4.** Observations in the continental interior of North America indicate that spatial coincidence between linear features, resulting from modern stream processes, and those that reflect the surface and near-surface

TABLE 7.4 INTERPRETATION OF LINEAMENTS

Identification No.	Description
M-I	This is a fracture running NW-SE. The fracture zone shows large apertures and is evident in one of the seepages/ springs which are tapped south of Manhere village.
A-II	A major fracture zone again trending NW-SE and cutting across the stream beds, is apparent. There are two master joints which trend NNW-SSE. A noteworthy feature of this fracture is the evidence of a spring aligned along it. Similarly the water table is shallow in wells along this fracture zone.
D-III	A very clear expression of the major fractures from within a fracture zone. The trend of the fracture zone is from NNW-SSE to NW-SE. For some distance, draomage is controlled by the fracture and the groundwater movement appears to be along this fracture zone in a south easterly direction with emergence as discharge into the stream through a larg cavity in vesicular basalt (spring development site of BAIF).

Contd....

P -IV	Pimparkane (NE of Pimparkane) Igneous intrusion aligned along major fracture running WNW -EES Location of spring developed by BAIF along this lineament.
P - V	One major fracture running NW-SE with the width of the fracture being 8 to 12 inches. Can be traced in the stream bed. The fracture appears to traverse several small basaltic flow units.

traces of deeper bedrock phenomena, such as fracture systems, is relatively common. Possible relationships between lineaments and surface drainage in the study area are shown in **Figure 7.2**. Some of the principal, geological factors, influencing success in the management of associated water resources, are listed. Appropriate strategies in water supply are also presented.

All of the main types of lineament are likely to exert a strong influence on the directional properties of ground- water flow on a megascopic scale :

- Regional fracture systems are not recognized as lineaments in Akole Taluka. However, the fractures, associated with the Narmada rift and other tectonic features of regional extent, may have coincided with the fissures from which Deccan lavas were released. Accordingly, distant fracture systems may have controlled the distribution of lava flows in Akole Taluka and adjacent areas, as well as lava properties, related to ground-water occurrence. Fractures, associated with the union of the Kurduvadi and Koyna rifts, which curves northwestwards, to the south of Nashik, probably influence the movement of deep ground water below the lavas in and near the study area.

- Local fracture systems occur throughout Akole Taluka. Agarwal (1994) grouped lineament orientations into six azimuth classes, corresponding to 30 degree intervals of the compass rose. Most observations fall in the range of 150 to 180 degrees; there is a secondary mode of 120 to 150 degrees. The vector resultant for the observations is 122 degrees. In general, the best ground definition is found at higher elevations, where the soil cover is of sporadic distribution, for example, on the hillside, to the north of Ambevangan. Vertical fractures, observed in a number of dug wells, coincide with lineaments, mapped from satellite imagery. Several of the wells were deepened to good effect during the project.

- Basalt dykes were observed at several locations in the study area. The width of these features ranges from a few decimetres to more than a metre. The orientation of the dykes is northwesterly and coincides with the trends of vertical fractures in the immediate vicinity. The degree of separation of a dyke from the adjacent country rock varies considerably.

However, vertical fractures transecting dyke rock are commonly seen at right angles to the dyke margins and are probably interconnected in depth. It is likely that dykes with trends, parallel to the orientation of the local fracture systems, are of common occurrence below the cover of superficial deposits. They merit careful consideration in future approaches to development of ground water.

- Alluvial valley fill reflects modern stream activity at intermediate to low elevations in the study area. Active deposition of material, eroded from higher elevations, by some of the longer-lasting, ephemeral streams is of particular interest, in that it provides a natural mechanism for the ongoing construction of shallow aquifers. Deposition of new aquifer material is easily controlled through the introduction of low barriers to streamflow at selected locations,. In this way, the tribal and rural people gained new land for agricultural use in the past. It is noteworthy that sand bodies commonly occur in neighbouring areas on the upslope side of culverts, where a road crosses a stream; bare rock surfaces generally are found on the downslope side of the road.

Shallow ground water in the sediment bodies, laid down by modern, ephemeral streams is readily accessed by means of dug wells and simple tube wells, not necessarily requiring the use of drilling equipment. In addition, the common coincidence of stream channels with deep-seated belts of weakness in the bedrock make these settings at the lower elevations prime locations for the siting of deeper bore wells.

7.5 GROUND WATER ISOTOPES

7.5.1 ISOTOPIC ANALYSIS, MAY, 1992

INTRODUCTION

On May 25 and 26, 1992, a reconnaissance survey of the ground water resources of the study area was conducted. As part of this survey, ground water samples were collected from serveral wells. All of the ground water samples were analysed in the field for electrical conductivity (EC) and samples were retained for later environmental isotope analysis. The purpose of analyzing ground water for these parameters was to gain some insight into the recharge processes that are operative in the area.

Electrical Conductivity

EC is a field parameter that can be related to the inorganic quality of water sample. Although there are no water quality criteria for EC, it is directly related to the total dissolved solids (TDS) concentration. According to Freeze and Cherry (1979), the relationship between the two parameters is : TDS = A x EC; where A varies between 0.55 and 0.75, depending on the ionic composition of the solution, where TDS is in mg/L and EC is in µs/cm.

Groundwater that contains less than 1000 mg/L of TDS is considered to be fresh. Since the recommended concentration limit for TDS in drinking water is 500 mg/L (Freeze and Cherry, 1979), EC values for drinking water should be less than about 650 to 900 μs/cm, depending on ionic composition.

Oxygen-18 and Deuterium in Hydrology

Oxygen-18 ($^{18}0$) and deuterium (^{2}H) are parts of naturally ocurring water molecules. Their concentrations in a ground water sample can be used to determine the nature and location of ground water recharge. The relationship between $^{18}0$ and ^{2}H also indicates the degree of evaporation that a water sample has undergone.

$^{18}0$ and ^{2}H concentrations in water are expressed in the standard delta (δ) in parts per mil (0/00) deviations from the Standard Mean Ocean Water (SMOW) standard. The mean annual $^{18}0$ value of precipitation in the study area should be about -2.0 0/00, according to Yurtsever's (1975) global survey.

Based on global precipitation surveys, the relationship between $^{18}0$ and ^{2}H concentrations is :

$$\delta^{2}H = 8.0\ ^{18}0 + 10$$

This relationship is called the global meteoric water line.

Precipitation in any given area may deviate slightly from this equation, but this equation is an acceptable assumption, where local data are not available. Water that has evaporated falls below the global meteoric water line on a $\delta^{18}0$-^{2}H, plot along a line with a slope of between 2 and 5. As waters become more evaporated, their $\delta^{18}0$ and $\delta^{2}H$ values become more positive. The intercept of this line with the global meteoric water line indicates the initial isotopic value prior to evaporation.

The $\delta^{18}0$ and $\delta^{2}H$ values of precipitation will change seasonally and may vary with elevation. Data on these variations are not currently available for the study area.

Methods

Table 7.5 gives the locations of the ground water samples collected in May 1992. Except for samples 7 and 8, all of the ground water samples came from large-diameter, open wells, completed in bedrock. Sample 7 was collected from a large fracture and sample 8 was collected from a pond in a streambed.

Whenever possible, water samples were collected from water flowing into a well, rather than from the standing water in the bottom of the well. This was possible at all of the wells except for samples 9 and 10. These two samples are from the Devgaon Shenit Phata well, before and after crudely bailing the well, respectively.

Electrical conductivity was measured in the field using a pHox model 52 portable conductivity meter. This instrument corrects readings to 25^{0}C. Electrical conductivity readings are expressed in μs/cm and are generally accurate to $\pm$5%.

Samples for isotopic analysis were collected in 8 mL glass bottles and sealed these securely in the field with electrical tape. These water samples were analyzed at the Isotope Laboratory, Department of Earth Sciences, University of Waterloo, for $^{18}0$

and ^2H content. $\delta^{18}O$ and δ^2H values have analytical errors of 0.2 and 2.0 o/oo, respectively.

Results and Discussion

At the time of this field investigation, the study area was experiencing severe drought. The wells and springs in the study area were either completely dry or they were producing only an extremely small amount of water.

In all but one or two locations, where sampling was done, the ground water that entered the wells came either from the soil or near-surface weathered rock. Flow from fresh, fractured rock was not observed. It was noted that wells drilled into bedrock, even deep wells, did not produce ground water.

Most, but not all of the observed wells, are located in valleys where the topography tends to collect ground water in the soil. Not all of this water appeared to be used. The soils on the slopes appeared to be thin, but still may be capable of delaying shallow, subsurface flow for months.

Table 7.6 summarizes the EC, oxygen-18, and deuterium data. Since the highest observed EC value was 530 µs/cm, all of the samples have EC values that indicate fresh ground water. In addition, all of the samples would be considered suitable in terms of TDS.

Figure 7.3 suggests that the more evaporated ground waters (more positive ^{18}O values) have higher EC values. For example, sample 8 has the highest EC value and the most evaporated ^{18}O value. This water is believed to be underflow from a surface reservoir. This water would be expected to be evaporated.

Figure 7.4 is the $\delta^{18}O$ - δ^2H plot for the data. This figure also indicates the EC values for the data. Since the data plot below the global meteoric water line, the water samples are evaporated. As expected, sample 8 is the most evaporated sample. Samples 9 and 10 are from the same well, before and after bailing. Evaporation of water from the well is suggested by the more positive $\delta^{18}O$ and δ^2H values and higher EC value for sample 9, the sample taken before bailing.

There is considerable local variability in the isotopic and EC values. Samples 1 and 2 were collected from wells that were probably no more than a few hundred metres apart yet the EC and isotopic data are significantly different. Sample 1 is from a communal well while sample 2 is from a private well. It is unlikely that the difference relate to use, but more likely, from position in the flow system. The sample 2 well is apparently up-gradient from the sample 1 well. Since the water table is close to the surface, these results suggest that water is being lost from the subsurface by evaporation.

Sample 7 was collected from a large fracture that may be a significant water source. In terms of the isotopic and EC data, it is not very different from sample 10 taken from a nearby shallow well. The implication here is that the water sources are similar and probably local.

TABLE 7.5 SAMPLE LOCATIONS AND DESCRIPTIONS

SAMPLE NUMBER	SAMPLE LOCATIONS AND DESCRIPTIONS
1	Gram Panchayat, Manhere Well, almost dry, taken from seeps at bedrock surface, bedrock about 3.2 m down.
2.	Somant Santu Binner, private well across road from # 1, bedrock at about 2.5 m, discharge from fracture.
3.	No sample. About 200 m north of # 1, nearly dry, bedrock at about 3.34 m.
4.	Mahadu Gopala Ghorpade, near # 1, downhill near stream, bare trickle, EC measured in standing pool, water issues from about 1 m. below bedrock, depth to Bedrock 0.9 to 1.9 m.
5	Ambewangan Navali, standing water, bedrock at about 0.5 m., well is off centre of gully.
6.	Ambewangan Kelech Band, bedrock at surface, miniscule flow, many hours to fill standard vessel. Titvi Bandh's Well No.1. No sample, about 0.6 m. of mud on bottom, Need to put wells in centre of valley
7.	Devgaon TAs, issuing from large fracture.
8.	Sample taken from ponded water in stream near # 7. Originates from a rainfall reservoir far upstream, flows underground.
9.	Devgaon shenit phata, pool of water in well, could be evaporated, associated with # 8 ?
10.	Same location as # 9, after standing water was removed and new water entered.

TABLE 7.6 ANALYTICAL RESULTS

SAMPLE NUMBER	EC (μS/cm)	Oxygen-18 (o/oo)	Deuterium (o/oo)
1	360	0.48	-3.97
2	230	- 1.57	- 7.08
4	380	- 0.8	- 3.49
5	360	0.46	3.21
6	260	1.16	- 6.43
7	345	- 1.02	- 8.31
8	530	6.42	29,35
9	420	0.46	- 0.54
10	270	- 0.51	- 4.37

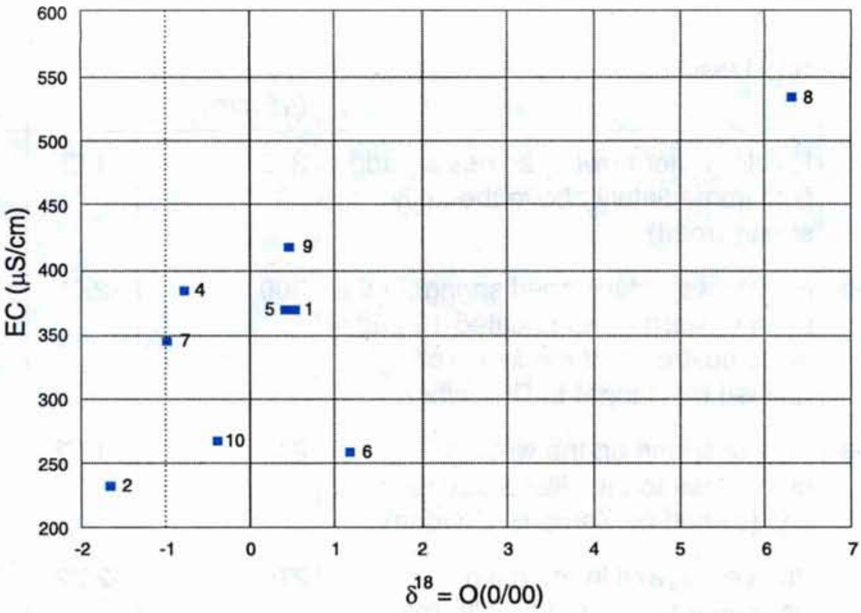


FIG. 7.3 ELECTRICAL CONDUCTIVITY VERSUS OXYGEN-18

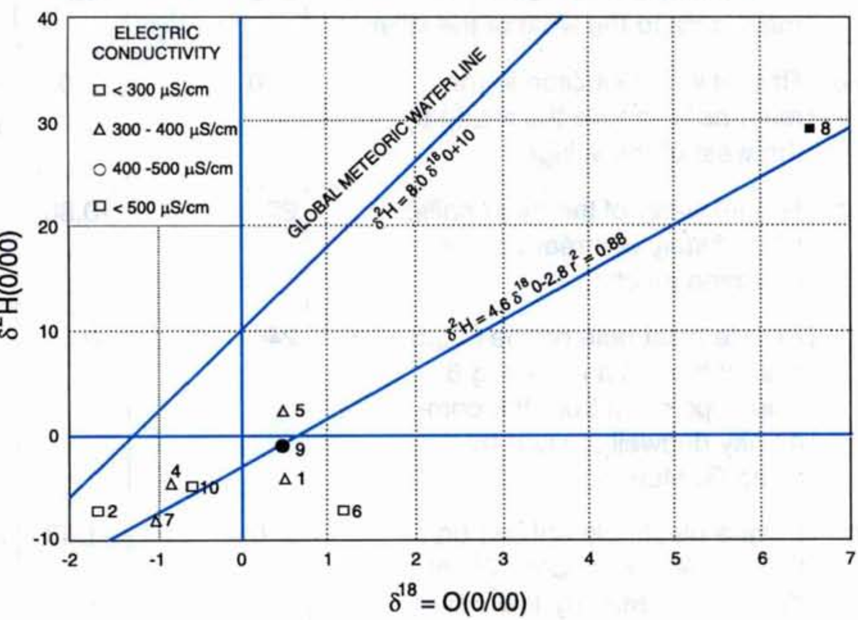


FIG. 7.4 DEUTERIUM VERSUS OXYGEN-18 DECEMBER, 1993

7.5.2 ISOTOPIC ANALYSIS, DECEMBER, 1993.

During the November-December field season of 1993, twenty-one surface water/ ground water samples and two rainwater samples were collected in the field in 30 ml. H.D. polyethylene vials. **Table 7.7** provides details about 11 samples that were selected for isotopic analysis. Each of the 11 samples was divided into three

TABLE 7.7 ELECTRICAL CONDUCTIVITY AND STABLE ISOTOPE VALUES FROM NOVEMBER-DECEMBER 1993

Sample	Site Description	Conductivity (μS/cm)	$\delta^{18}O$ (0/00)	$\delta^{2}H$ (0/00)
1Amb-a	Rivulet water flowing across a paddy field immediately above the *kelly* spring (road).	310	-1.65	-3.07
2 Amb-b	Private well (developed spring) in the main eastern *nalla*. Located 16 paddy fields upstream of the *kelly* spring (owned by Ganpat L. Dhandhe).	300	-2.06	-3.77
3 Amb-e	Private spring on the western ridge close to the village boundary. (owned by Sama B. Dhadhe).	240	-1.52	-0.37
4 Man-a	Private dugwell in the main *nalla* near the end of the dirt road. (owned by Maruti G. Gobhale).	270	-2.22	-3.35
5 Man-d	Community bored well in the main *nalla* to the west of the village.	240	n/a	-0.94
6 Man-e	Rivulet water junction in the main *nalla* (above the road) to the west of the village.	170	-2.03	-0.88 [-2.25]
7 Titvi-c	Rivulet water of the main *nalla,* immediately upstream of the Devgaon junction.	225	-0.86	3.34 [2.75]
8 Titvi-d	Private blast hole on the south side of the main *nalla* and 6 fields upstream from the community dugwell (owned by Nana G. Mundhe).	240	-0.69	3.29
9Titvi-g	Private blast hole (inflow) on the northeastern ridge. Water drainage is easterly towards Devgaon *nalla* (owned by Sakharam B. Mundhe).	210	-1.43	3.61
10 Titvi-k	Community bored well on the hilltop adjacent to the village (52 m ?).	170	-0.98 [-.93]	4.15
11 Rain	BAIF office at Manhere.	n/a	n/a	-72.13

smaller volumes at the Geology Department, University of Windsor. A portion of each of the 11 samples was subjected to stable isotope line extraction to prepare CO_2 samples. The CO_2 samples were sent to the University of Ottawa, Department of Geology, for ^{18}O analysis. Analytical errors of 0.2 o/oo are associated with triplicate ^{18}O values. Unfortunately, ^{18}O values were not obtained for two of the samples (Rain, Man-d), due to the absence of CO_2. Another portion of each of the 11 samples was analyzed at the Isotopic Laboratory, Department of Earth Sciences, University of Waterloo for ^{2}H content. Analytical errors of 2.0 o/oo are associated with triplicate ^{2}H values. The samples were selected in an attempt to isolate different sources of water on the basis of stable isotope signatures. The samples selected represent surface waters, shallow ground water and deeper ground water from bore wells.

Sample Collection

Three of the 11 samples were rivulet waters (Amb-b, Man-e, Titvi-c), collected from valley bottoms in the study areas. Man-e was collected at a rivulet emergence point, adjacent to a bore well (Man-d)

Five of the 11 samples were collected from private springs/blast holes and dug wells (Amb-b, Amb-e, Man-a, Titvi-d, Titvi-g) of both study areas. Amb-b was collected at the surface outflow from a spring receiving surface water from three seepages from the paddy field bund above. All three seepages appeared to be from the soil-weathered basalt contact. There was no evidence of surface rivulet flow on the paddy field above the spring. Amb-e was collected from a spring at relatively high elevation (close to the Manhere boundary). The surrounding area was relatively flat and densely vegetated. The soil was relatively thick around this spring and the weathered basalt was 1-2m deep on an exposed hillslope on the west side of the spring. The village guide informed the group that this spring dried up after the springs and wells at lower elevations. Man-a was collected from a typical dug well in the main nalla of the Manhere part of the study area. Approximately 0.5 m of soil lay over an unknown thickness of weathered basalt. The landowner stated that the well dried up in April/May. Titvi-d was collected from blast hole that was located at a spring where, according to the landowner, the water was usually gone by February. Titvi-g was collected from an inflow (fracture) to a blast hole at high elevation on the opposite side of the Titvi study area from the vilage. The landowner claimed that the water remained all year round.

Two of the remaining three samples were collected from bore wells (Man-d, Titvi-k). Man-d was collected from a bore well of unknown depth in the *nalla* bed that provides water all year round. Titvi-k was collected from a bore well of approximately 52 m depth (BAIF information), which does not produce water all year round.

The remaining sample was collected from the water running off the roof of the BAIF office at Manhere on December 6th.

The Titvi samples were collected on December 4th and the Ambevangan/Manhere samples were collected on December 10-12th. During the interval between the two sampling times, a seasonally unusual rain event (>20mm) occurred on December 5-6th. This rainfall was caused by a tropical storm from the eastern seaboard, which progressed inland. The rain was depleted in terms of ^2H content (-72.13 o/oo), but it is unknown if this ^2H signature is characteristic of the rainfall during the regular monsoon season. This rainwater mixed with the slightly evaporated ground water contained within the shallow aquifers of the Manhere/Ambevangan study area, thereby altering their ^2H signature.

Results

Figure 7.5 is a plot of δ^2H *vs.* $\delta^{18}O$ for nine of the samples. The majority of the samples plot above the Global Meteoric Water Line and are linearly related, according to the following :

$$\delta^2H=5.148\,\delta^{18}O + 7.896 \qquad r^2 = .76$$

The above regression violates the assumption of n>20, so it is not possible to determine if the sample data are normally distributed. Therefore, the slope and intercept values of the above equation should be considered as crude estimates of the population parameters they represent.

The effect of the rain on the Manhere/Ambevangan samples is evident as they show up as being more depleted (larger negative values) relative to the Titvi samples. The isotopic signature of the bore well sample (Titvi-k) suggests that the water is from the same source as the shallow ground water and surface water. This is in agreement with BAIF records, which indicate that this bore well runs dry during the pre-monsoon season and it only produces water after receiving fresh water during the monsoon season.

Figure 7.6 is a plot of conductivity *vs* ^{18}O for nine of the samples. No clear relationship exists between the two parameters. The more enriched (evaporated) samples from Titvi tend to have lower conductivities than the samples collected after the rainfall event. This is reflective of rainwater runoff, containing more suspended and dissolved solids than baseflow. There are two interesting exceptions. Man-e seems to be an exception, having relatively low conductivity and relatively low ^{18}O content. This may be indicative of subsurface source of ground water, which had not mixed with any sediment-laden rainwater runoff. Amb-e seems to be an exception having relatively high ^{18}O content, compared to the other samples, collected after the rain event. This could mean that the amount of rainwater mixing with the subsurface water was proportionally less at that particular sampling site, which was at the highest elevation of all samples collected.

Figure 7.7 is a plot of conductivity *vs* ^2H for all ten of surface water/ground water samples. It supports the observations made of Figure. Man-d is a bore well water sample, which is similar to Amb-e, in that they both do not seem to have been altered (isotopically) by the rainfall as much as the other samples, collected at the same time.

Summary

The results of the few selected samples show that the bore well waters are of similar isotopic signatures as the surface and ground water in the study areas and

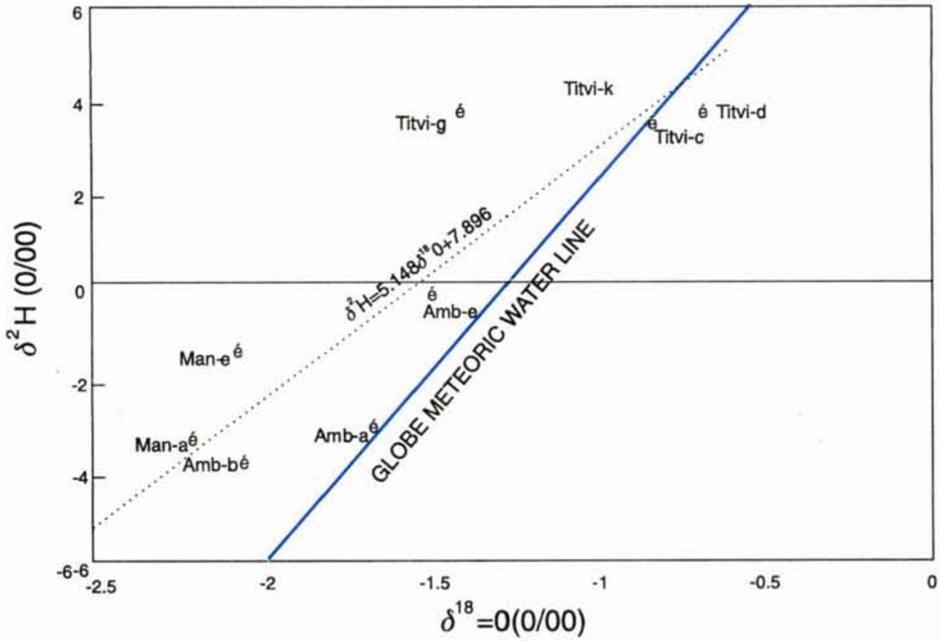


FIG. 7.5 DEUTERIUM VS. OXYGEN-18 DECEMBER,1993

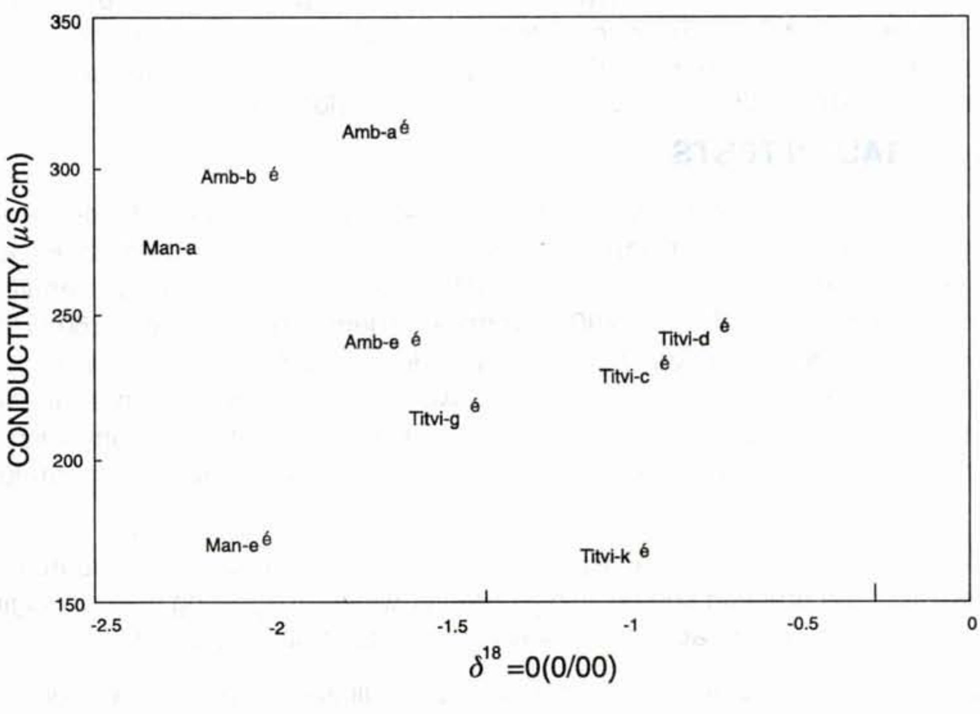


FIG. 7.6 CONDUCTIVITY VS. OXYGEN-18 DECEMBER, 1993

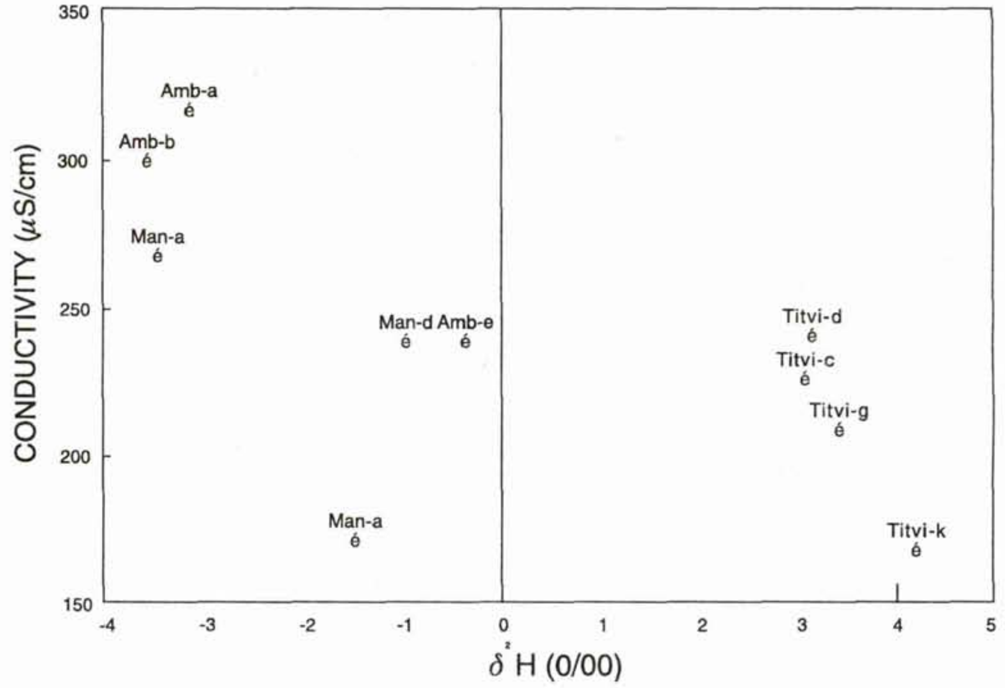


FIG. 7.7 CONDUCTIVITY VS. DEUTERIUM DECEMBER, 1993

there is no evidence of alternative, deeper sources of ground water. Results from two samples point to the need for further investigation. The samples Man-e and Amb-e are possibly indicative of relatively large sources of shallow subsurface water, which should be examined with a view to development.

7.6 RADON TESTS

Bedrock geology is the main control on radon distribution. Background radon levels in a basalt terrain are relatively low, because basic igneous rocks are characteristically low in uranium content. It follows that basaltic-type rock aquifers are also low in radon. Michel (1990) reports radon levels in the range of 260 to 550 pCi/L for these aquifers in comparison to granitic-type rock aquifers, which usually have radon levels greater than 8000 pCi/L. Additionally, soil gas radon levels vary from day to day and season to season, because of environmental factors, such as soil moisture, precipitation, barometric pressure, soil temperature, air temperature and wind (Asher-Bolinder *et al.*, 1991).

Radon moves through permeable pathways and can often be detected hundreds of meters from the uranium source. Some ground-water prospecting methodologies use radon as a natural tracer in areas with suspected fracture porosity.

It was feasible that some of the water sources available during the pre-monsoon season were supplied water by a deep-seated fracture or seepage and an anomalously high radon concentration in soil gas above the site may confirm the existence of ground water with origins other than the basalt bedrock. Radon soil gas measurements were taken in the study area at locations, where both suspected lineaments and possibly related water supplies existed. Sample transects were placed across suspected lineaments, in order to check for unusual radon levels over the lineaments that might indicate deep groundwater sources, associated with the structures. Four sites were monitored for radon soil gas concentrations. **Annexure 11** provides details about the sites with test locations. The soil gas levels were measured with a portable Rn200 Radon Detector, equipped with a 150 V2 scintillation cell, provided by Instruscience Ltd. The cell sensitivity was 0.5 CPM/pCi/L. An active sampling method was employed as a hand vacuum pump continuously drew soil gas through the cell for a seven-minute count period. One-meter lengths of steel pipe with slotted bottoms and sealed tops were used to obtain soil gas samples from 75 cm below soil surface. The steel pipes were installed in hand augured holes.

Observations Of Study

All soil gas radon levels were in the range of 309 to 838 pCi/L (11 to 31 Bq/L). No anomalous radon levels were discovered. Radon concentrations over the suspected lineaments were similar to concentrations measured on either side. Soils in the study area are fine-textured (silt loams) and of low permeability and thus a hindrance to the movement of soil gas. The sampling points in such an environment may have to be very close to the radon source (e.g. water in a fracture belt - defined as a lineament) in order to identify the anomaly. In this study, there is evidence of short term variation in radon levels, indicated at the radon-2 site. At the same sampling location (pipe), the radon concentration on May 15th was half that, measured on April 30th. This short-term variation at the same sampling location was greater than any measured difference between sampling locations along the same transect. The data collected do not eliminate the sites as sources of ground water, originating from basement rocks. This is in agreement with the environmental isotope data from water samples, collected on two occasions by the University of Windsor team.

7.7 BOTANICAL INDICATORS OF SHALLOW GROUND WATER

Plants that extend their roots down to the zone of saturation in dryland regions are termed phreatophytes (Meinzer, 1927). They are surface indicators of relatively shallow occurrences of the water table throughout most of the year and also mark the sites of springs and seepages (Cannon, 1971). Accordingly, a knowledge of the phreatophytes, occurring in a dryland region, has potential to serve as a useful starting point in the selection of sites for future dug wells and spring developments. In some dryland regions, phreatophytes are found in ecological communities of plants, which frequently have the common characteristic of taking water from the saturated zone and may occur in such numbers, as to seriously deplete the shallow ground water locally through transpiration losses.

The importance of plants as local indicators of shallow ground water in dryland regions was well known in ancient India. One of the earliest, documented records of this is found in the *Brahat Samhita*, written by *Varaha Mihira* in the Sixth Century, and described in recent accounts, such as those by Murty (1987) and Tagare (1992). For example, the ancient text identifies associations of particular plants that are indicators of shallow ground water, such as *Aegle memelos* with *Ficus glomerata* and *Prosopis specigera* with *Butea frondosa*.

In recent time, Thigale (1979) drew attention to the importance of *Eugenia* species as indicators of shallow ground water in the Western Ghats of Maharashtra, while Thigale and Tavate (1979) commented on the phreatophyte nature of *Prosopis spicigera,* also in western Maharashtra. Thigale and Sen (1982) described associations of these and other plant species as a bottomland flora in parts of the Deccan Trap.

The tribal and rural people of Akole Taluka revere several plants for their medicinal and other properties. *Ficus glomerata* is worshipped locally, on account of its affinity to shallow ground water. The local name of this plant is umbar. Typically, it grows in the thin soil cover and in the weathered bedrock of hillsides, and also extends its roots into the sporadic, vertical fractures that break the lateral continuity of the bedrock. In all such modes of occurrence, these trees mark the sites of springs and seepages, The villagers have sited dug wells immediately below occurrence of *F. glomerata* and a number of these wells were selected for deepening during the course of the project. Several of the springs, developed during the project, likewise were associated with this tree. Accordingly, the occurrence of *F. glomerata* augmented the use of lineaments as an important field indicator of shallow ground water.

◆◆◆◆

8: WATER RESOURCE MANAGEMENT STRATEGY

The purpose of the project was to provide the tribal and rural people of Akole Taluka with a management strategy for acquiring a year-round water supply. Initially, the focus was on water for domestic use. Early in the project term, it was seen that an effective strategy required reduction of the amount of water, leaving the area around the collaborating villages as runoff. This could only be achieved through an understanding of runoff processes on the scale of a watershed.

The most promising technologies for reducing runoff comprised a wide range of approaches to water-harvesting and-spreading. Some of these has been tried and tested over many centuries in dryland regions. They included technologies, used by the Nabotean culture and its predecessors (Nessler, 1980) up to four millennia ago in the Negev Desert. It was clear that no single technology held the complete solution to the problem in Akole Taluka; rather a combination of approaches was needed. In addition, efficiency of water use on a watershed scale dictated that attention be paid to agricultural, as well as domestic uses.

A combination of measures to impound water behind surface barriers and to direct runoff underground into the porosity of shallow aquifers appeared likely to achieve the best results over wide areas around the villages. It was deemed appropriate to supplement these measures with strategies for reduction of the velocity of runoff on hill-slopes. This gave the additional, beneficial effect of reducing soil erosion.

Clearly a high priority was assigned to the selection of technologies, acceptable to and readily understood by the tribal and rural people. The indigenous, technical knowledge of the area included the use of barriers across streams and modification of hillslopes as part of local agricultural practice. Accordingly, the introduction of water and soil conservation techniques as project demonstration sites built upon these existing, local practices.

The development of springs as a part of the project activities likewise took local practice in water utilization as a starting point. As well, selected dug wells, in use by the tribal and rural people, were deepened for improved water yield during the course of the project. In addition, selected borewells in the area were given maintenance checks and repairs by BAIF staff from Vansda, Gujarat.

In all these project activities, the knowledge of the tribal and rural people with regard to features of the terrain was used to good effect. The information on botanical indicators of ground-water occurrence, obtained from ancient texts and from local people, was applied extensively.

Artificial catchments, already present in the area were put to use in the project, with only minor modification, to serve a water-supply function. The tiled roofs of houses, occupied by the tribal and rural people, held greatest promise in this regard. Eavestroughs and connected pipes, leading to storage tanks, were added to selected dwellings in each of the collaborating villages.

A masonry checkdam : Manhere village

Another type of artificial surface with potential for use as a catchment is provided by the roads, linking the villages. Though of variable quality, these roads are commonly flanked by sharply defined gutters, excavated into the weathered bedrock as a source of road material. Already monsoon runoff from the roads flows in the gutters to lower elevations and is easily directed into the adjacent fields.

Table 8.1 outlines the main, intermediate-technology approaches to water conservation and utilization, adopted in the water-resource management strategy of the project.

- Techniques, referable mainly to the surface circuit of the hydrologic cycle, use barriers (contour bunds, *nalla* bunds, checkdams, gabions) and shallow excavations (contour trenches, farm ponds, bedrock excavations), as well as natural and artificial catchments. They complement the soil-conservation function of the terraces on hillslopes under agricultural cultivation; exploit the short-lived, channelized flow of ephemeral streams; and also take water from road surfaces and roofs of dwellings.
- The subsurface circuit of the hydrologic cycle is harnessed by means of shallow excavations to enhance recharge (recharge pits and trenches) and at other locations, to contain discharge of ground water (spring development), and through improvements to existing dug wells and borewells for aquifer development. Simple tanks and other structures have been installed for development of springs and seepages. Underground dams (artificial aquicludes) were also employed.

This division is to some extent artificial in that some of the breaks in slope of the first category also facilitate the infiltration of ponded waters. As well, alternative techniques for the extraction of water from the atmosphere as evaporation/condensation waters (modified Mexican still, solar still) and dew ponds were presented for possible survival use by separate families and individuals, under conditions of extreme water shortage.

The main body of this chapter is made up of detailed accounts of the main technologies, introduced into the area for the purpose of water-resource management. Every attempt was made to follow a consistent format, with stages in the system life cycle (planning, acquisition, use) as the main frame of reference.

TABLE 8.1 : Main Techniques For Water Conservation And Utilisation, Akole Taluka, Maharashtra, India

Circuit of Hydrologic Cycle	Conservation/ Utilisation Technique	Status	Remark
Surface circuit	Gravity-flow systems	Implemented	Application to intermediate and high elevations. Water collection, in single intake or connected, on-stream basins. Particularly good potential for development along fracture traces.
modifications	Catchment area	Implemented	Including cultivated areas. Contour bunding to control runoff and reduce soil erosion. Management of monsoon surface flow through openings in bunds sequentially downslope, starting at highest terraces. Gully plugs and contour trenches.
	Artificial, soil-covered and bedrock catchments	Implemented in part	Includes slopes with exposed bedrock, corrugated sheeting catchments, and treated, coated or covered soil surfaces, including dirt roads and flanking gutters. Water directed to artificial recharge system.
	Farm ponds	Implemented	V-shaped upslope valley terminations in bedrock, depressions below springs, depressions to catch diffuse surface flow, all with bunds downslope. Excavated basins and natural depressions.
	Nalla bunds, check-dams and percolation basins	Implemented	Mostly at intermediate and low elevations. Main objectives are trapping of sediment and infiltration for ground water recharge. Ferrocement gabion across streams for water storage.
	Shallow bedrock excavations	Implemented	In rock exposures near groups of dwellings, fed from both on-stream and off-stream types of farm ponds and roof intake systems. Rock exposures in beds of ephemeral streams, especially downslope from road crossings.
	Roof Water harvesting	Implemented	Collection in ferrocement tanks, plastic cisterns. Tile and corrugated sheeting roofing material, eavestroughs and gathering systems. Possible linkage of eavestroughs of several, adjacent dwellings in a single gathering system, connected to one tank.
	Fog and mist collection	Planned	Crushed stone in piles on bedrock slopes, polyethylene sheets and nets as traps.
	Dew ponds	Implemented	Shallow depressions lined with clay insulating as demonstration material (e.g. straw) cool more rapidly than surrounding land.
	Evaporation traps	Implemented as demonstration	Modified Mexican still could trap evaporation waters on lower surface of cover, dew from condensation of atmosphere on upper surface. Simple, solar still employs polyethylene sheet over shallow surface depression

Circuit of Hydrologic Cycle	Conservation/ Utilisation Technique	Status	Remark
Subsurface circuit	Use of indigenous technical knowledge	Implemented	Village ITK on ground-water discharge phenomena and approaches to water treatment. Ancient texts, e.g. *Brahat Samhita* of Varaha Mihira (Sixth Century) on biological indicators of shallow ground water
	Environmental	Implemented education	Emphasis on sanitation related to water use, especially with regard to alternative approaches to water storage at low elevations. THIS IS ESSENTIAL TO HEALTH OF HUMANS AND LIVESTOCK.
	Aquifer development	Implemented	Soil, weathered bedrock, bedrock aquifers. Improved siting of bore wells and hand-dug wells, taking into account basic principles of groundwater flow . Enhancement of performance of existing wells by deepening, hydrofracturing and horizontal drilling.
	Artificial recharge	Implemented	Recharge pits and trenches with mulches to reduce soil erosion and evaporation losses. Plastic liner added late in monsoon for pond use. Diversion ditches from streams and roadside gutters to infiltration trenches and basins.
	Artificial aquifers	Implemented as ITK	Sediment traps along ephemeral streams, especially upstream of road culverts to increase thickness of valley-fill sands and gravels. Installation of tube wells in valley-fill aquifers. Coordinated use of upstream valley-fill aquifers and downstream bedrock surface.
	Artificial aquicludes	Implemented	Plastic sheets and/or subsurface stone dams in contact with bedrock valley sides and floor. Recharge pits and trenches in superficial deposits on upslope sides of barriers. Grouting of fractures downslope.
	Spring development	Implemented	Springs are rock discontinuities and lava tunnels. These can be further developed to augment water availability; may coincide with lineaments on satellite imagery.

8.1 CATCHMENT TREATMENT

Contour Trenching

Name of Technique	Catchment Treatment	
Brief Description	Main Design Elements	Rainfall intensity, rainfall distribution, annual rainfall, runoff, infiltration rate of soil, depth of soil, nature of bed rock, slope of land, present and proposed land use.
	Site Characteristics	Different techniques used for catchment treatment based on above factors. All types of land can be treated with different measures, like contour trenches (uncultivated land), gradonies, bunding, contour vegetative hedges, terracing, vegetation cover on land.
Planning	Concept Formulation	Aims for catchment treatment include following : a) waste lands and degraded agricultural lands treated for converting them into productive lands. b) conservation of soil and water resources. c) reduction of runoff and increase in infiltration rate of rainwater to improve ground water reserve.
Acquisition	Site Preparation	*In-situ* soil and water conservation measures before development of vegetation cover.
	Materials	For barriers across slope local soil (stone for steep slope) and grasses like vetiver. For vegetation cover, productive, multipurpose tree species, recommended by the scientists and short-listed by the local community
	Installation/ Construction	Barriers across slope are created using local material. Plantation is done along barriers/buns in agricultural lands and plantation and pasture is developed in non-agricultural land.
Use	Operation	Trenches, earthen bunds, vegetative hedges or vegetation cover on soil reduces runoff and its velocity. This reduces soil erosion and increases infiltration of rain water. Impact is better soil fertility, more ground water and hence more production.
	Maintenance	Soil/stone/vegetative measures need periodic maintenance to function effectively.
Remarks	Outcome/ Impact	Sustainable development of land and rainwater resources.

8.2 INFILTRATION PITS

Mr. R. M. Dabhade a field officer, standing on the infiltration pit

Name of Technique	Infiltration Pits	
Brief Description	Main Design Elements	Topography of location. Type of land use. Type of strata, Availability of filtering media. Rate of infiltration of soil. Rainfall and runoff.
	Site Characteristics	Cultivated land, Impermeable top soil, Potential water utility on downstream area, Potential reservoir / aquifer characteristics of strata underneath top soil.
Planning	Concept Formulation	Impervious top soil of farm lands leads to high surface runoff effecting high rate of erosion. Need of increasing soil moisture of land. Need to develop water resources in downstream locations.
	Operational Requirements	Making user community aware. Demonstration for developing local skills for future execution, Availability of filter media.
Acquisition	Site Preparation	Digging pits of 2-3 sq. metre area and depth to permeable strata.
	Materials	Stones of varying size.
	Installation/ Construction	Filling up of pits in three layers. Bottom layer with boulders, middle layer with gravel/pebbles and top layer with pervious soil/sand.
Use	Operation	Surface water infiltrates through filters. Hence reduces surface runoff, increases soil moisture level, increases sub-surface flow, increases ground water availability and augments downstream water sources. Top layer of soil allows uninterrupted farming.
	Maintenance	Periodic cleaning of blockages in filtering media.
Actual Work Done	Where Located	In upper/middle reaches of catchment.
	Quantity	Two lines of infiltration trenches and 18 pits have been constructed in project area.
	Main difference in planning/ acquisition/use	Infiltration trenches which is nothing but modified form of infiltration pit. Single strip is located across slope to augment existing spring used for drinking water.
Remarks	Outcome/Impact	Augments downslope water sources.
	Constraints/ Limitations Observed	More pits per unit area reduces moisture level of field in which they are located. Farmers are resistant to adopting technique as sometimes it develops voids below ground.
	Alternative Strategies	In uncropped lands, open contour trenches (without refilling the trench/pit with any material) are excavated.

8.3 DRY STONE BUND

Dry stone bund controlling the runoff & hence soil erosion in village Manhere

Name of Technique	Dry Stone Bund	
Brief	Main Design **Description**	Slope of gully/nalla. Depth of gully. Elements
	Site Characteristics	Upper reaches of catchment. In gullies just formed or nalla branches.
Planning	Concept Formulation	High velocity of flows in *nallas* hence more deepening and erosion. Structure constructed across nalla breaks down velocity of flow, which ultimately results in settlement of sediments in *nalla* and thus reduces soil loss.
	Operational Requirements	Acceptance by villagers facilitated by similarities to local practice.
Acquisition	Site Preparation	Cleaning of unwanted shrubs etc. from proposed site of structure.
	Materials	Stones.
	Installation/ Construction	Excavation up to 0.3 to 0.5 m for foundation, Erection of stone wall with 0.5h:1v side slopes with keying of wall up to stable portion into banks of nalla.
Use	Operation	Silt in flowing water settles in storage area of structure due to lowering of flow velocity.
	Maintenance	Repairs if any breakages occur and increasing height periodically.
Actual Work Done	Where Located	In upper/middle reaches of catchment.
Remarks	Outcome Impact	Reduces soil erosion. Controls deepening of gullies. Scope for plantation of economic value trees in sediment.
	Constraints/ Limitations Observed	In high rainfall areas with sloping terrain, structure does not withstand high velocity floods in middle/lower reaches.
	Alternative Strategies	If stones are not available locally then earthern structure can be constructed. However requirements for earthen structure, like suitable place and strata for spillways, should be available.

8.4 GABION STRUCTURE

A field officer observing the performance of gabion structure

Name of Technique	Gabion Structure	
Brief Description	Main Design Elements	Slope of *nalla*. Depth of *nalla*. Velocity of runoff.
	Site Characteristics	Upper and middle reaches of the catchment, Stable nalla banks, Straight stream flow. *Nallas* with high velocity of runoff.
Planning	Concept Formulation	If velocity of flow in *nalla* is very high, traditional stone bund cannot sustain it and gets washed out. At such places bund constructed out of stone and wrapped in galvanized iron chainlink withstands the force of water, because it reacts against flood as unit.
Acquisition	Site Preparation	Cleaning of unwanted shrubs etc. from proposed site of structure.
	Materials	Stones, G. I. chainlink of 15cmx15cm size and wire diameter of 3mm.
	Installation/ Construction	Excavation of foundation; placing G.I. chainlink along proposed site; construction of stone bund and binding chainlink around the bund. Sides raised up and also embedded into banks up to stable portion of bank. Construction of downstream pitching.
Use	Operation	Silt in flowing water settles in storage area of structure due to lowering of flow velocity. Temporarily stored water accelerates recharging.
	Maintenance	Repairs to breakages. However it is rarely required.
Actual Work Done	Where Located	In upper/middle reaches of catchment
	Quantity	Total number of gabions constructed in study area is 25.
Remarks	Outcome/Impact	Conserves soil, recharges ground water.
	Alternative Strategies	See section 8.5

8.5 GABION STRUCTURE WITH IMPERVIOUS BARRIER

Mr. B. K. Kakade observing the performance of a gabion with ferrocement barrier; structure developed during project implementation

Name of Technique	Gabion Structure with Impervious Barrier	
Brief Description	Main Design Elements	Slope of *nalla*. Depth of *nalla*. Velocity of runoff.
	Site Characteristics	Upper and middle reaches of catchment, Stable nalla banks. Straight stream flow, *Nallas* with high velocity of runoff. Impervious strata for foundation and in banks.
Planning	Concept Formulation	Gabion structure if provided with impervious barrier (right from impervious foundation strata up to top level) retains water. Constructed as a low-cost alternative to traditional checkdams in microwatersheds.
Acquisition	Site Preparation	Cleaning of unwanted shrubs etc. from proposed site of structure.
	Materials	Stones, G. I. chainlink of 15cmx15cm size and wire diameter of 3mm, Waterproof material - impervious clay/ferrocement.
	Installation/ Construction	Excavation of foundation down to hard impervious strata; filling/ constructing impervious barrier in foundation trench; placing G.I. chainlink along proposed site; construction of impervious barrier at centre or on upstream side of proposed structure; construction of stone bund and binding chainlink around bund. Sides raised up and also embedded in banks up to stable portion of bank. Construction of downstream pitching.
Use	Operation	Structure stores water, due to impervious barrier constructed along it. Support of gabion structure for impervious barrier withstands force of water.
	Maintenance	Repairs, if any breakages occur. Not much required otherwise.
Actual Work Done	Where Located	In upper/middle reaches of micro-catchments.
	Quantity	One structure with clay barrier and two structures with impervious barrier of 1 inch thick ferrocement were constructed.
Remarks	Outcome/Impact	Effective, low-cost water-storage structure in micro-watershed development programmes.
	Alternative Strategies	See section 8.4

8.6 MASONRY CHECKDAMS

Masonry checkdam : Manhere village

Name of Technique	Masonry Checkdam	
Brief Description	Main Design Elements	Slope of *nalla*. Depth of *nalla*. Peak rainfall intensity and peak runoff. Annual rainfall. Catchment characteristics.
	Site Characteristics	Middle and lower reaches of catchment. Stable *nalla* banks. Straight stream flow. Hard foundation strata. Shallow foundation depth. Gentle *nalla* slope
Planning	Concept Formulation	Traditional structures (checkdams) have been constructed for satisfying need of drinking water of locals, also for demonstration of runoff water harvesting and optimum water utilization.
Acquisition	Site Preparation	Cleaning of unwanted shrubs etc. from proposed site of structure.
	Materials	Rubble, sand, cement, aggregates.
	Installation/ Construction	Excavation of foundation down to impervious strata. Placing PCC in 1:3:6 for bedding; construction of main UCR masonry wall in cm 1:4. Side walls raised up and also embedded into banks up to stable portion of bank. Construction of downstream pitching.
Use	Operation	Structure stores water and helps in recharging water and raising water table.
	Maintenance	Repairs, if any breakages occur.
Actual Work Done	Where Located	In middle/lower reaches of micro-catchments.
	Quantity	Three checkdams have been constructed in study area under the project.
Remarks	Outcome/Impact	Water is used for drinking and protective irrigation.
	Constraints/ Limitations Observed	Structure becomes very expensive, if foundation depth goes below 1.5 to 2.0m. Masonry checkdam is risky structure (in terms of money) in areas with fractures/dikes.
	Alternative Strategies	Earthen structure can be constructed in place of masonry if overall cost comes less than for masonry.

8.7 FARM POND

Farm pond : Ambevangan village

Name of Technique	Farm Pond	
Brief Description	Main Design Elements	Type of soil/rate of infiltration, rainfall intensity / runoff / catchment availability. Size-5mx5mx2m up to 20mx20mx3m
	Site Characteristics	Low point of natural depression. Favorable spillout conditions. Minimum excavation in hard strata, Strata should not have rocks containing crevices, sinks or channels, sandy or silty soils, fractures.
Planning	Concept Formulation	• For storing and infiltrating water into ground if trenching / bunding is not sufficient, dugout ponds in area stores surplus water. • Dugout pond for water storage sometimes serves as alternative to checkdam, where the topography does not permit storage of water by constructing embankments. • Localised source is sometimes needed for protective irrigation of crops or for nursery raising, drinking water for livestock, humans.
Acquisition	Site Preparation	Identifying exact location by digging trial pits. Deciding upon inlet and outlet arrangements based on topography and land-owner's requirements. Demarcation of excavation area and area of disposal of excavated materials.
	Materials	Stones for pitching.
	Installation/ Construction	After demarcating limit of excavation and soil placement, then pond is excavated. Side slopes of pond are kept at natural angle of repose of strata. The bund is protected, either by stone pitching or developing grass cover on it. Provision of inlet and outlet arrangements.
Use	Operation	Surface water first enters into filter, provided at inlet of pond. Here sediments in water get settled/trapped and clean water is then stored in pond, Water stored serves purpose for which it is required. Ground water recharging or irrigation or drinking or fishery use.
	Maintenance	Periodic cleaning in blockages of inlet arrangement (either small, dug holes or gravel filter) and maintenance of bund.
Actual Work Done	Where Located	On hillslopes and in natural depressions.
	Quantity	Total ponds in study area are 19.
Remarks	Outcome/Impact	Downside, agricultural area retains more soil moisture and hence increases production of crop. Water is used for irrigation.
	Alternative Strategies	Ponds used for sole purpose of water storage are lined with masonry, plastic, ferrocement, concrete or clay

8.8 USE OF FRACTURES FOR WATER-RESOURCE DEVELOPMENT

A fracture

Developed fracture for water exploitation

Name of Technique	**Use of Fractures for Water Resource Development**	
Brief Description	Main Design Elements	Potential water utility. Catchment area. Catchment characteristics. Horizontal and vertical extent of fracture.
	Site Characteristics	Shallow water table in fracture, Potential of water use mainly for drinking and also for irrigation, Water yield through fracture, Location at lower reaches of catchment.
Planning	Concept Formulation	While excavating bank of *nalla* for foundation of proposed checkdam, fracture was detected and then excavated up to 3.5m below ground level. At that depth water was observed and yield in month of May (1995) was 100 liter/hour. Looking to potential of fracture, catchment area was treated with water recharge measures. This fracture is now supplying water to one hamlet in summer.
	Operational Requirements	A small rectangular well (3x4feet) has been constructed with steps for withdrawal of water.
Acquisition	Site Preparation	Finding potential of source, horizontal and vertical extent of fracture.
	Materials	Rubble, sand, cement, aggregates for casing of well.
	Installation/ Construction	Fracture is excavated at appropriate level for getting water and then masonry casing is constructed for protection of source.
Use	Operation	Water recharging measures applied in catchment increase water availability in fracture. This water is then exploited for the use in drinking or irrigation.
Remarks	Outcome/Impact	There is potential for developing and utilizing ground water from fractures.
	Constraints/ Limitations Observed	If terrain is hilly/undulating or with extensive vegetation cover, detection of extent of ground feature, impossible, due to lack of low-cost/easily available technology.
	Alternative Strategies	Various, possible alternatives depending on relationship between fracture trace and slope of ground.

8.9 ARTIFICAL AQUICLUDE

Underground barrier using ferrocement

Name of Technique	**Artifical Aquiclude**	
Brief Description	Main Design Elements	Potential water utility. Catchment area. Catchment characteristics. Storage area. Soil type of storage basin, Rainfall intensity. Annual average rainfall. Runoff Infiltration rate of soil.
	Site Characteristics	Location that forms closed basin. Moderate *nalla* slope. Width of stream not more than 50m. Aquifer with good transmitivity.
Planning	Concept Formulation	If site conditions permit storage of water in subsoil and withdrawal, then it has several advantages. Underground structure is easy to construct, requires low capital, labour intensive no risk of structural failure, reduced evaporation losses of water.
Acquisition	Site Preparation	Minimum disruption of agricultural practice at surface.
	Materials	Sand, cement, aggregates, rubble
	Installation/ Construction	Trench is excavated in bed and extended into (about 15-30cm) impervious strata; core wall, using UCR masonry, is then constructed in trench and finally gaps on both side of core wall refilled by soil.
Use	Operation	Subsurface flow is checked due to impervious wall across *nalla*, and stored below ground. This raises water table and water yields of wells in nearby area.
Remarks	Maintenance	No repair and maintenance required, unless leakage is detected in impervious wall.
	Outcome/Impact	Water can be stored below ground
	Constraints/ Limitations Observed	Underground structure should be constructed avoiding leaks. Small gap/void left in core wall defeats whole purpose of structure. Structure constructed in sloping terrain is most susceptible to failure. Sanitary practices of local people a limiting factor.
	Alternative Strategies	Instead of UCR masonry other material like ferrocement, clay etc. can be successfuly used.

8.10 ROOF WATER HARVESTING SYSTEM

Village man using water from roof water harvesting tank

Name of Technique	Roof Water Harvesting System	
Brief Description	Main Design Elements	Daily demand of family. Water scarcity period, Surface area of roof. Rainfall intensity and rainfall distribution over a period for calculation of capacity of water storage tank.
	Site Characteristics	Roof water harvesting tank is located at such place that foundation depth will be minimum and inlet pipe length is also minimum.
Planning	Concept Formulation	Areas with water scarcity in summer season, but receiving medium to high rains in monsoon and post-monsoon period, are typical areas where localized water harvesting system becomes suitable. Study area receives rains up to October/November, which can be stored for use in scarcity period.
Acquisition	Site Preparation	Cleaning of site. Constructing platform for tank
	Materials	Rubble, sand, cement, aggregates, wiremesh, steel bars of 6mm diameter
	Installation/ Construction	Preparing chicken wire mesh cage and placing it on platform prepared for tank. Then cage is plastered with mortar of 1:2 ratio. Wash out overflow and drinking water taps are provided to tank. Roof water collecting troughs are prepared out of galvanized iron sheets and water thus collected through troughs is taken to tank by PVC pipe.
Use	Operation	Rain water falling on roof is collected through troughs and ferrocement tank is filled. This water is then used as and when required by family.
	Maintenance	Regular cleaning of tank and roof is necessary.
Actual Work Done	Where Located	In front of house.
	Quantity	Twenty-six systems have been installed in three project villages.
Remarks	Outcome/Impact	Rain water of tank is used not only in scarcity periods, but is also used in all seasons. Along with drinking, water is also used for kitchen gardens, bathing etc. in monsoon and winter seasons.
	Constraints/ Limitations Observed	To inculcate habit of use of roof water for drinking, high level of motivation of community is required in areas, where it is not traditional practice. If potability of water is not ensured, it may create health hazards.
	Alternative Strategies	Underground water tanks are also used in many parts of country.

8.11 DEVELOPMENT OF SPRINGS AND WELLS

A developed spring in village Ambevangan

Name of Technique	Spring Development	
Brief Description	Main Design Elements	Use of spring water. Discharge of spring water. Duration of flow. Dependent population/Daily demand.
	Site Characteristics	Location of spring. Distance from residential area. Potential for augmentation of water.
Planning	Concept Formulation	Traditionally, locals collect water pot-by-pot from natural springs. After drying up of open wells, springs are main sources of drinking water. If such seepage is collected in tank, it will provide good water for longer periods and keep hygienic conditions around source. It becomes easy to collect tap water from tank and trough provided near to tank also provides clean water for livestock.
	Operational Requirements	Preparing user community for development and maintenance of water source.
Acquisition	Site Preparation	Cleaning path of water and site for locating proposed filter and tank.
	Materials	Stones of varying size, gravel, sand for filter, cement, sand, aggregates, rubble, outlet taps for storage tank and cattle trough
	Installation/ Construction	Provision of gravel filter at Inlet of storage tank; construction of water storage tank. Washout, drinking water and overflow pipes/taps and manhole for cleaning of tank. Cattle trough on downstream side of tank.
Use	Operation	Natural seepage travels through a gravel filter and clean potable water is collected in tank. During night time tank is filled up and water is then taken from taps by community residing near source.
	Maintenance	Periodic cleaning of blockages of filtering media and water tank. Introduction of small fish in water tank.
Actual Work Done	Where Located	Existing natural seepage points.
	Quantity	Four more springs have been developed at other locations in area.
Remarks	Outcome/Impact	Effective method for collecting small amounts of seepage water in tank for drinking by community in scarcity periods.
	Constraints/ Limitations	Water use should be kept at minimum near the source. Livestock should be kept away from developed springs.
	Alternative Strategies	Possible use of horizontal well at spring site to improve yield.

8.12 ENVIRONMENTAL EDUCATION

At the first village meetings, attended by members of the Canadian and Indian project teams, the tribal and rural people spoke of their desperate need for a reliable, year-round water supply. The villagers placed a high priority on improved access to water; they emphasised that the quality of the water source was of secondary importance.

A major challenge, addressed throughout the project term, was to impress upon the villagers the importance of water quality to the maintenance of good health. In particular, the message that basic hygiene and sanitation make important contributions to the preservation of both water quality and human health was communicated in a variety of ways: at the village schools; at formal village meetings; attended by a large section of the community; and at gatherings of farmers near at newly completed demonstration sites.

The widespread occurrence of human and animal feces in the vicinity of each of these villages exerted a significant constraint on the selection and siting of particular technologies, especially at the early stages of the project. For example, this consideration rendered the use of underground barriers and artificial aquifers inappropriate in close proximity to a village, in spite of an otherwise favorable, hydrogeology environment.

Toward the end of the project term, there was evidence that some villagers had taken the message about water quality to heart. Women strained well water through *sari* material to remove particulate matter. Farmers were seen, tending to the water needs of livestock downslope from a water source. Farmers requested instruction in procedures for the cleaning of dug wells. The number of pit latrines in use showed a steady increase in all three villages.

At a series of village meetings, held in 1995, the suggestion was made to the women that they take on the role of "environmental managers", assuming responsibility for the spread of the message about hygiene and sanitation, among other matters. It was pointed out that an arrangement of this kind works well in African villages. The response was very positive, but accompanied by the comment that "it will take time".

◆◆◆◆

9: APPROPRIATE TECHNIQUES FOR CONJUNCTIVE USE OF WATER RESOURCES

9.1 FIELD LEVEL RAINFALL MEASUREMENT AND ANALYSIS

9.1.1 RATIONALE

The rainfall information for the project area is one of the most crucial design inputs in the planning and design process. This is because rainfall shows extreme variability, not only from day to day during the season, but also from hour to hour. As a result averages are often meaningless. Designs of water-harvesting structures have to be based on actual peak intensities during storms. Dimensions of infiltration measures, such as trenches, also depend on the rainfall distribution, in order to maximise the arrest of run-off and attendent infiltration.

Often, in a country like India, secondary rainfall data from rain gauge stations is available. Such data can be used for gross estimations, but are subject to the following limitations :

- The data are generally available as daily totals, which does not give any idea of the occurrence of storms. The peak intensities can therefore be calculated only as an average.
- In transition zones, where the rainfall pattern changes very sharply, the existing rain gauge stations may not give even a reasonable idea about the actual rainfall pattern at the site. There may be an under- / over-estimation of peak hourly rainfall, as well as total rainfall.
- Estimation of peak hourly intensities on the lower side would lead to under-designing of water storage structures and under-estimation of catchment area treatment measures, as well as under-utilisation of run-off water either for storage or for infiltration. On the other hand, estimation of the peak intensities on the high side would lead to over-designing of structures and excessive catchment area treatment. This in turn will unnecessarily push up costs.

In view of the above factors, it is worthwhile to go in for on-site rainfall measurement in the following stages:

- As the first step, a simple, manual rain gauge should be installed.
- It is recommended that an automatic rain gauge with / without a data logger be installed in the case of transition zones and if the daily rainfall pattern is known or observed to be considerably different from the nearest rain-gauge station data.

A simple, manual rain gauge can be easily installed in an open area and the accumulated rainfall measured regularly once a day. **Section 9.1.2** provides the specifications of the equipment and site preparation for installation. An automatic rain-gauge with a data-logging arrangement enables continuous monitoring of the rainfall and easy retrieval of the stored data using a lap-top. Typical specifications for such a unit are provided in **Section 9.1.3**.

The data collected needs to be properly analysed and used as a design input in the watershed development plan. As one proceeds from the gross (monthly rainfall data) to the detailed (hourly rainfall data), the variations start becoming more and more sharp. **Figures 9.1, 9.2 and 9.3** provide the rainfall pattern in the village Manhere, Taluka Akole of Ahmednagar District, for the year 1994, as monthly, daily and hourly rainfall information. **Figure 9.3** also shows the storm events for 15/08/94 of the Manhere raingauge station. **Figure 9.4** provides the rainfall during the same year for two rain gauge stations at Manhere and Bhandardara locations. Rainfall data should be analysed with respect to various parameters. **Annexures 9A and 9B** provides daily rainfall data from the Bhandardara and Manhere stations. **Table 9.1** gives the following:

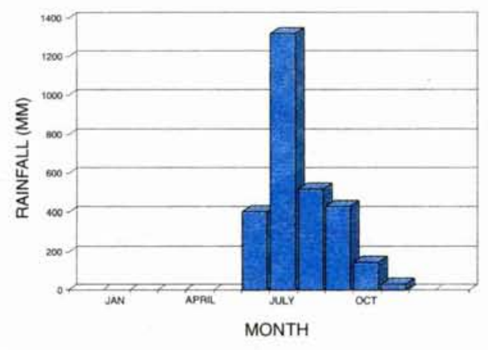


FIG. 9.1 MONTHLY RAINFALL OF 1994 : MANHERE STATION

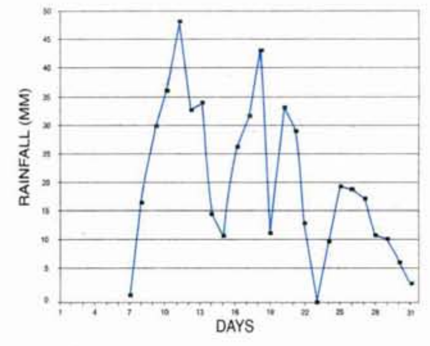


FIG. 9.2 DAILY RAINFALL TREND OF AUGUST 1994 : MANHERE STATION

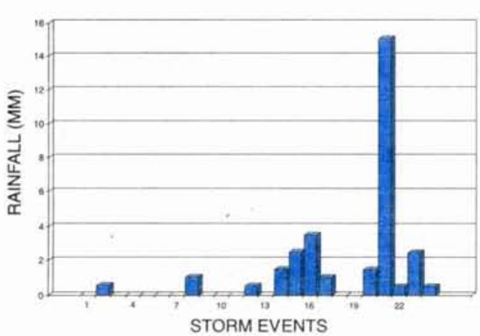


FIG. 9.3 STORM EVENTS OF 15/08/1994 : MANHERE STATION

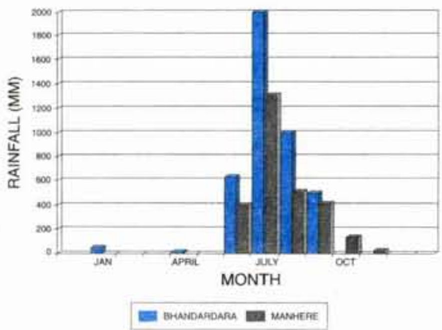


FIG. 9.4 MONTHLY RAINFALL OF BHANDARDARA AND MANHERE

- Total and average rainfall
- Number of rainy days
- Number of storms events
- Peak intensities
- Run-off estimation
- Implications for water storage structure design
- Implications for area treatment

Section 9.1.4 gives the design of graded bunds for the Manhere watershed area, using the peak intensity of the Manhere raingauge station with a recurrence interval of 2 years.

Table 9.1 Rainfall Analysis Of Manhere And Bhandardara Stations In mm (1994)

Sr. No.	Description	Rainguage Station	
		Bhandardara	Manhere
1	Total rainfall	4225.5	1665
2	No. of rainy days	106	95
3	Average daily rainfall a. All days basis b. Rainy days basis	 11.577 39.863	 7.6969 29.572
4	Peak intensities a. All days basis b. Rainy days basis	 0.48 1.66	 0.3207 1.2322
5	Peak hourly rainfall mm/hr		15
6	Storm events (15.8.94) a. Numbers b. Average spacing in hours		 5 3.4

9.1.2 SPECIFICATIONS FOR MANUAL RAINFALL MEASUREMENT

For the collection of accurate rainfall data, it is necessary to install the raingauge properly and also to measure the rainfall records correctly. Some of the important specifications for manual rainfall measurement as per the Indian Standard Code of Practice IS: 4986 - 1983 are given below.

Exposure of Raingauge

Following points are considered for selecting the location for raingauge station.

- The site of raingauge should be a level ground.
- The distance between the raingauges and the nearest object is generally

four times the height of the object. In exceptional cases, it can be upto two times of the height of object.

- On mountains and coast stations, a belt of trees or a wall on the side of the prevailing wind at a distance mentioned above forms an efficient shelter.
- If it is difficult to find a level space in hilly area, the site for the gauge can be with a minimum level area of 6 x 6 m, where it is best shielded from high winds and where the wind does not cause eddies.

INSTALLATION OF RAINGAUGE

The raingauge is fixed on a masonry or concrete foundation 600 x 600 x 600 mm sunk into the ground. It may also be fixed using steel structurals or wooden planks as shown in **figure 9.5**. Into this foundation, the base of the gauge is cemented so that the rim of the gauge is exactly 300 mm above ground level. This height is necessary to prevent more than a negligible amount of water splashing into the gauge. If the height exceeds 300 mm, the amount of rain collected decreases owing to wind eddies set up by the gauge. Top of the gauge should be perfectly level.

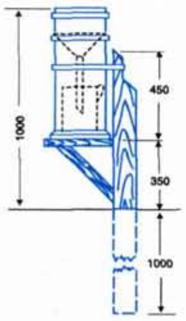


FIG. 9.5 : INSTALLATION OF RAINGAUGE USING WOODEN PLANKS

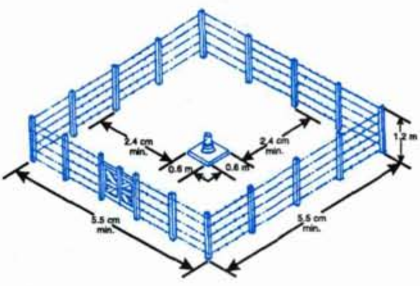


FIG. 9.6 : A RAINGAUGE INSTALLED WITHIN FENCE

PROTECTION OF RAINGAUGE

To protect the raingauge from being damaged, a fence is erected around it as in **figure 9.6**. Top of the fence should not be higher than half the distance of the fence from the gauge.

MEASUREMENT OF RAINFALL

The procedure for rainfall measurement is given below.

- To measure the rainfall, pour the rain water into the glass measuring cylinder. Take the reading of the bottom of the curved surface of water (meniscus). If the bottom surface of the water rests between two divisions, the rainfall is estimated to the nearest 0.1 mm.
- The rainfall is measured every day at 08.30 hour Indian Standard Time.
- A written record of the rainfall measured at 08.30 in Indian Standard Time each day, is entered against the date of measurement.

- If it is raining at the time of observation, possible errors are avoided by completing all the operations quickly and with use of a spare bottle.
- If the bottle has overflowed, the overflow receiver is taken up, and its contents measured and added to those of the bottle. If there is water in the overflow receiver when the bottle is not full, the bottle should be examined for leaks.
- The observer should be trained before being given charge of a raingauge station.

9.1.3 SPECIFICATIONS FOR AUTOMATIC RAINGAUGE STATION

The automatic raingauge station installed in the project area was supplied by Dynalab Weathertech Private Limited . The details of rainfall sensor model DTR 8104 of Dynalab are given below.

Raingauge	Tipping Bucket Raingauge
Sensing	Magnet and Reed Switch
Resolution	0.5 mm
Accuracy	1 mm
Rim Diameter	203 mm
Collecting Area	325 mm
Material	Raingauge Shell made of (FRP) Fibre glass Rainforced Plastic Bucket and Mounting assembly of Brass and (SS) Stainless Steel.
Capacity	Unlimited
Sensitivity	0.5 mm (Rainfall per pulse)

This instrument produces an electric pulse every time it receives a predetermined quantity of rainfall (16.5 ml of water for 0.2 mm of rain)

The body and the funnel are made of FRP while the rim is made of Gun metal. All parts having contact with water are made of SS.

The mechanism consists of a tipping bucket provided at its centre. Rain water is collected in the upper half. When this is full, the mechanism tilts and discharges the collected water, allowing the other half of the bucket to start filling. Alternate filling and discharging continue so long as rain is falling and at each tilt a magnet momentarily closes the contact of a reed switch, generating a pulse.

9.1.4 DESIGN OF GRADED BUNDS

For showing the effect of rainfall intensity on design of water resource development structure, a sample design of graded bunds is given below. The design is as per the guidelines given in the Katyal *et.al.,* 1995.

Design criteria	based on concept of stable channel.
Soil type	light soils with shallow depths.
Maximum length of terrace	150 m
Average slope S	5%
Minimum cross section of bund for shallow soils and bunds with vegetative protection	0.3 sqm.
Rainfall intensity	
2 years recurrence interval	46.5mm/hr.

(Automatic raingauge station in project area)

a Vertical interval V.I. = (S/a + b) x 0.3

where a = constant with value = 3.0; b = constant with average value of 2.0

So, VI = (5/3 + 2) X 0.3 = 1.1 m

b Average width of terrace W = VI/S x 100 = 1.1/5 x 100 = 22 m

c Inter terrace area A = 150 x 22 = 3300 m2 = 0.33 ha.

Runoff coefficient (for the area) C = 0.27

Longitudinal gradient = 0.5%

Rainfall Intensity, I = 46.5 mm/hr.

Peak discharge Q = CIA/360 = (0.27 x 46.5 x 0.33)/360 = 0.0115 cumec.

Assuming a watersheet flowing along bund with 0.10 m depth, the flow area becomes:

c/s of flow = 1/2 (2.002+0.1) = 0.1051 m2

The wetted perimeter for this section is 0.141+2 = 2.141 m

Hydraulic radius R = A/P = 0.105/2.141 = 0.049

According to Manning's formula, V= (R2/3 S1/2)/n = {(0.049)2/3 x (0.005)1/2 }/ 0.05

= 0.189 m/sec.

Velocity is safe

Q = AV = 0.1051x0.189 = 0.01988, say = 0.0199m3/sec.

It follows that the bund will have following dimensions :

Top width	= 0.3 m
Side slopes	= 1:1
Height of bund	= 0.4 m
Base width	= 1.1 m
VI	= 1.1 m

Note : From the isohytal map the hourly rainfall intensity for the project area is 90 mm/hr (for a 10 -year recurrence interval). This shows that the intensity from isohytal maps is twice that actually seen. The comparison is with 2 years against 10 years. Despite this, there is a big difference. Hence the design of bunds or any other storage structure will be over-designed by isohytal map intensity.

9.2 ROOF WATER HARVESTING TECHNIQUE

The priority need identified by the community residing in the study area, was water for drinking. Although the area receives significant rainfall (1500 mm) in the monsoon, the scarcity of water starts in March and continues up to the next monsoon. In the project area, the population is widely scattered, because of the distribution of farms. Accordingly, many hamlets do not receive the water supplied by the Zilha Panchayat during the scarcity period, so the people have to walk long distances to fetch water.

In addressing the problem of drinking water, a localised water harvesting system for individual households was conceived. The idea was well received and accepted by the people, which led to the introduction of roof water harvesting systems. People appreciated the cost-benefit relationship, the durability of the construction and the use of simple techniques. Another significant reason could be the traditional practice in the area of collecting roof water with hollow bamboo poles in empty kerosene barrels. This was however limited to a few households and the water thus collected was used for purposes other than drinking during the monsoon. Based on domestic consumption during the scarcity period, a 2500-litre tank appeared sufficient (and affordable) to meet the needs of one family.

The traditional method of fetching water from the source (with metal vessels on the head) was estimated to take about 3 to 5 hours daily to fulfil the needs of a family of five. Efforts have been made to reduce that time and energy expended solely by womenfolk. Estimate of water requirement :

Daily requirement per capita	15 litre (drinking, cooking, etc.)
Average family size	= 6 members
Daily requirement per family	= 6 x 15 = 90 L.
Total requirement per month per family	= 90 x 30 = 2700 L.

An affordable unit of 2500 litres was thus decided.

The volume of tank	= 2.5 m^3
The surface area of roof	= 6 x 3 = 18 m^2
The rainfall required to fill up the tank	= 2.5 m^3 / 18 m^2
	= 0.1388 m = 138.88 mm

Compensating for losses, in the order of 150 mm of rainfall is required. The rainfall data indicate that the area receives this much rainfall in the month of October, which is the last month of the rainy season.

A roof water harvesting system : Manhere village

The total number of roof water harvesting systems installed in the study area under the present project is 19.

Contributions from families to the cost of installation is about 30 %.

Surprisingly, the systems proved to be useful in all the seasons. Benefits observed and narrated by the people are as below:

Rainy Season

In this season, the water stored was used for washing, for cattle, for bathing and even for drinking. Kitchen gardens were also maintained by using this water as protective irrigation in the dry spells.

Since the area is hilly and wells are located in the valleys, it is difficult for women in hamlets to fetch water from such wells during heavy rains. Hence the stored water is used extensively for various purposes. The water is covered and then used for drinking.

Winter Season

The water was used for drinking, kitchen gardens, washing, and for other purposes. Generally, post-monsoon rains are active till late October and the tanks can be refilled by the end of November, as most of the families did. The stored water was then used for almost a month thereafter. Subsequently, the family refills the tank by water from nearby sources.

Summer Season

During the summer, water is not available in the village (Gavthan), as well as in the hamlets. Provision of water through tankers was not available to the families in the hamlets. Usually, these families had to fetch water from 2 to 3 km every day. Now the tanks are filled by water, brought from available sources by bullock carts, and is used during this period.

Community Perception

Although the tanks were promoted for the storage of drinking water, the community perception was different. They felt that since pure and fresh water is essential to maintain good health, stored water cannot be used for drinking. Although this was the initial reaction, since the families have to depend on the tanks for drinking water during the scarcity periods, they gradually accepted tank water as potable. The stored water proved to be useful during village gatherings, marriages and other community activities. The first impression of a woman from one of the beneficiary families was encouraging, as she confirmed that the new systems were useful for womenfolk in saving time and energy, which can be put to good use elsewhere. During the scarcity period, the entire family is busy fetching water from early morning. This effort should be avoided, as they also need to reach work sites for earning their daily bread.

The systems have been installed by involving trained, local youths. They were at BAIF's training centre, at Vansda. Repairs and maintenance will also be handled by them. The entire family contributed their labour during the installation and construction of the tanks. This resulted in on-the-job training for family members in the techniques of repair and maintenance.

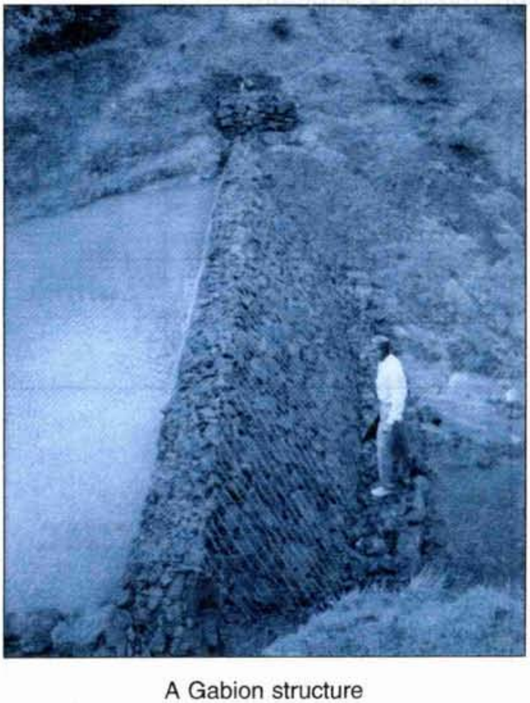
9.3 GABION STRUCTURE

9.3.1 INTRODUCTION

For conservation of soil and water, stone bunds are generally constructed in series in the *nallas* of the upper and middle reaches of the catchment area. The purpose is to reduce the velocity of flow, which leads to the settlement of silt in the *nalla* beds. However simple stone bunds do not withstand the high run-off velocities, created by high rainfall intensities and sloping lands, and get washed away with the flood. In such cases, gabion structures are effective.

In a gabion structure, the whole stone bund is bound in chainlink. Due to this it becomes a single, heavy unit and withstands the thrust of the water. With time and after 3 to 4 rainy seasons, silt gets trapped in to the voids of the stone masonry wall and vegetation grows on it, thus forming a solid mass, which can store water.

9.3.2 METHODOLOGY OF CONSTRUCTION



A Gabion structure

The methodology of construction of a gabion structure is given below :

- Clean the site where the structure is to be constructed.
- Excavate the gully bed up to a minimum depth of 0.3 meters.
- Lay down the galvanised chainlink of size 6" x 6" and 10 swg along the section of the proposed checkdam. The quality of chainlink plays an important role in durability and strength of the gabion.
- Construct a stone bund with locally available stone.
- The structure should go 0.3 to 0.6 meters into the stable portion of gully sides to prevent end cutting.

- Bind the structure with GI wire of 20 gauge.
- The sides are raised to provide sufficient water way in between to discharge the maximum runoff from the catchment and to avoid side scouring.
- On the downstream side of gabion an apron is provided if the bed is not hard enough to withstand water hammering from the bund. This prevents scouring of the bed. The thickness of apron packing should not be less than 0.45 meter and gully sides above the apron have to be protected with stone pitching to a height of at least 0.2 meter above the anticipated maximum water level. This work in turn prevents sides scours being formed by the falling water.

9.3.3 ADVANTAGES OF GABIONS

1. **Flexibility.** In uneven, sinking foundations gabions can bend without breaking. Where there is some unequal settlement on the foundation, these structures do not collapse like rigid structures.
2. **Permeability.** Gabion structures are highly permeable and act as self-draining units. Seepage or baseflow is easily drained off and the structures are thus safe against hydrostatic pressure.
3. **Stability.** A gabion is a heavy unit, able to withstand water thrust.
4. **Economy.** With little additional cost of chainlink structure this achieves stability comparable to a permanent masonry structure.

9.3.4 TYPE DESIGN (FIGURE 9.7)

The recommended dimensions for gabion structure are given below.

Nalla bed width	15.0 m
Length of structure	19.0 m
(2 m keying on either sides)	
Top width	0.6 m
Side slopes u/s & d/s	0.6 : 1
G.I. Chainlink : Size	15cmx15 cm
Wire dia	3-4 mm
Height above G.L.	1.0 m
Depth of foundation	0.6 m

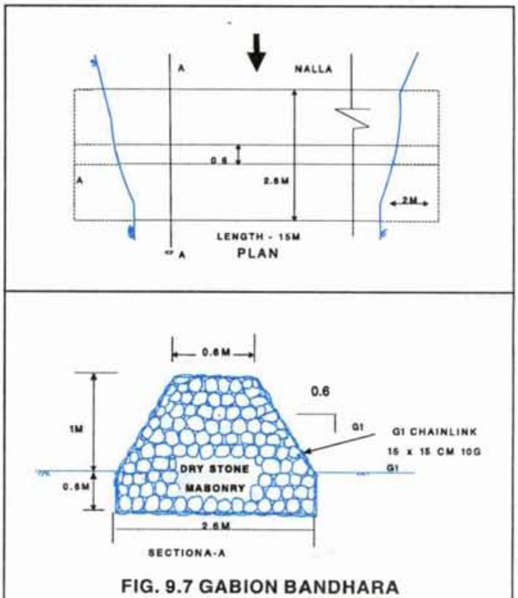


FIG. 9.7 GABION BANDHARA

9.4 GABION STRUCTURE WITH FERROCEMENT IMPERVIOUS BARRIER

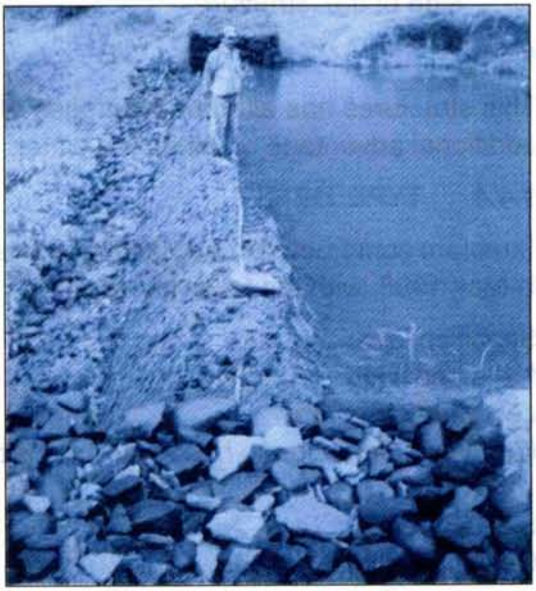
9.4.1 INTRODUCTION

Based on its field experience, BAIF has modified the gabion to incorporate an impervious ferrocement barrier, thereby improving its water-retaining ability.

This structure is similar to the gabion structure, except it has a ferrocement impervious wall at the centre of the structure, which goes below ground level down to bedrock. Due to this impervious wall, the structure stores water, if the foundation strata is impervious. If the strata of storage area are pervious, then the structure acts as a percolation tank and hence it raises the water table.

9.4.2 CONSTRUCTION

The material requirement with specifications and the construction methodology is described below:



A Gabion with Ferrocement impervious barrier

MATERIALS LIST

- Locally available stone.
- Galvanised Iron (GI) chainlink.
- Cement, sand and aggregates for concrete.
- Cement, sand, 6mm dia. mild steel bars and chicken mesh (15mm x 15mm, 18 gauge) for ferrocement.
- Water proofing powder.

METHODOLOGY

- First clean the site.
- Excavate the foundation trench down to the hard strata.
- Lay down concrete of 1:3:6 proportion, 15 cm. thick for the ferrocement foundation.
- Construct the ferrocement wall at the centre of the foundation trench down to 7.5 cm below ground level. Fill the upstream and downstream sides of ferrocement with sand about 15 cm thick and the remaining trench with available soil. The sandy layers have a dual function. They:
  - protect the ferrocement from the swelling action of the surrounding soil; and
  - allow the water sprinkled on top for curing of the ferrocement to percolate to the bottom.
- Next provide 7.5 cm thick concrete of 1:2:4 proportion on the ferrocement wall. Place G.I. chainlink of size 15 cm x 15 cm and 3 to 4 mm diameter GI

wires on it. Lay the remaining 7.5 cm thick concrete above the earlier layer so that the chainlink gets fully embedded in the concrete. As this chainlink is used to bind dry stone masonry, it should be of good quality to ensure the durability and strength of the gabion.

- Construct a ferrocement wall above this concrete up to the full supply level of the structure.
- Construct a stone bund keeping the ferrocement wall at the centre.
- The whole structure, including the ferrocement core wall, should go up to 30 to 60 cm into the stable portion of gully side to prevent end cutting.
- Raise the end portions of the structure to the level equal to the flood depth plus free board to prevent scouring of the nalla banks.
- On downstream side of the structure, provide 2-2.5m width rubble soling along the full length. This helps to prevent soil erosion on the down slope side of the structure.

9.4.3 ADVANTAGES

This structures has all the advantages of a gabion, as described above, plus the additional advantage of the stored water.

9.4.4 TYPE DESIGN

Structure constructed in Ambevangan village of Akole Taluka, Ahmednagar District in May 1995, with the following details:

Specifications	
Nalla bed width	16.0 m
Length of structure	23.0 m
(7 m keying and due to head wall extensions)	
Top width	0.6 m
Side slopes	1:1
G.I. Chainlink :	
Size	15cm x 15 cm
Wire dia	3-4 mm
Height of structure above bed level	2.4 m(Max.)
Depth of foundation	1.0 m
Average	1.5 m
Max.	2.7 m
Core wall	
a. Bed concrete	1:3:6
b. Concrete at bed level in which chainlink is embeded	1:2:4
c. Wall	25 mm thick ferrocement
Chickenmesh size	125mm x 12.5mm
Wire diameter	1mm
Cement : Sand ratio	1:2.5

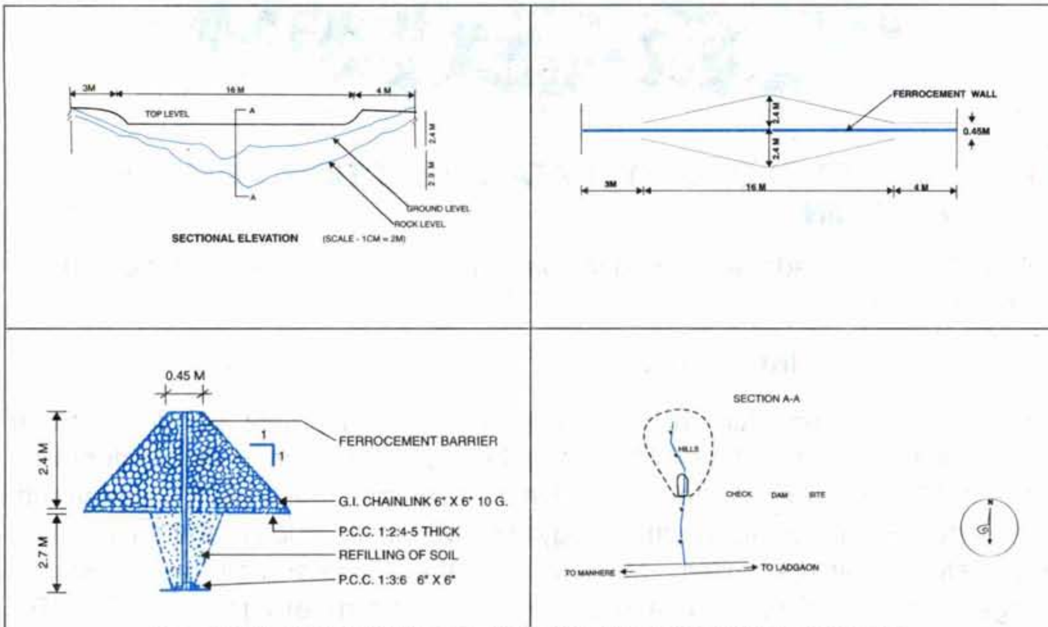


FIG. 9.8 GABION STRUCTURE WITH FERROCEMENT IMPERVIOUS BARRIER

Table 9.2 Expenditure Statement

(Structure Constructed At Ambevangan Village Tal. Akole, Dist.Ahmednagar In 1995)

Sr. NO.	Item	Quantity	Unit	Rate Per Unit	Amount
1	Survey, site cleaning etc.	Lump sum	-	-	200.00
2	Excavation for foundation and disposing the stuff as directed.	26	Cum	18	468.00
3	PCC 1:3:6 for bed concrete	2.0	Cum	1295	2590.00
4	PCC 1:2:4 at nalla bed level	1.8	Cum	1733	3119.40
5	Ferrocement impervious wall with supports	48	Sqm	218	10464.00
6	Filling sand on either side of ferrocement wall (7.5 cm thick) and filling soil in the gaps on either side	15.25	Cum	30	457.50
7	Constructing dry rubble masonry for gabion	41.91	Cum	85	3562.35
8	Providing and binding the chainlink to masonry wall	180	Sqm	33	5940.00
9	Providing and constructing the apron on d/s side of gabion	6.37	Cum	55	350.35
	TOTAL				27151.60

◆◆◆◆

10: METHODOLOGIES, IMPACTS AND RECOMMENDATIONS

10.1 METHODOLOGY FOR DATA COLLECTION, ANALYSIS AND PLANNING

The methodologies adopted during the project implementations for various studies are given below.

10.1.1 PROJECT INITIATION

The concept of undertaking a research study for development and use of water resources was perceived by BAIF during the implementation of the Wadi project between 1989 and 1992. After finalisation of the programme, initiation started with Participatory Rural Appraisal methodology to convey ideas amongst the communities and to study their responses. Meetings with the villagers in all three proposed villages was the first step of the project. Those meetings and PRA/RRA methodologies helped strengthen relations with the community and to introduce teams from the University of Windsor and BAIF, Pune.

The information generated through the RRA has helped in formulating an entire strategy for planning and implementation of the proposed project theme. The transect walks in the study area included visits by the project teams to all parts of the selected micro.watersheds. Some ground features like exposed fractures in rocks, caves and dykes observed in the area gave the direction for the proposed study. As a result of this, it was decided to study satellite imageries for developing potential ground features.

10.1.2 BASELINE DATA COLLECTION

The data required to crystallise the project concept were collected in the first year of the project. These included demographic information, education levels, land holding pattern, livestock ownership, agricultural production and income assessment. A questionnaire in the local language was prepared to cover all these aspects. All households residing in the project villages completed their questionnaires. The survey was conducted by BAIF field officers, who had established a good rapport with the villagers. The information was then analysed to obtain results in a specific form as summarised in this report in the form of charts and graphs. Specific studies to meet the priority needs of the people were drawn up on the basis of this information.

10.1.3 METEOROLOGICAL DATA

The Indian Meteorological Department (IMD) has established raingauge stations at various places all over the country. The State Irrigation Department has also established stations on their irrigation project sites. Annual rainfall recorded (from

1960 to 1991) at the Bhandardara, Akole, Waki and Randha (Bk.) stations was procured from IMD. The distance of these stations varies from 3km to 30km from the project area. The data collected were then analysed for an understanding of the variability in rainfall from area to area and the probability distribution of annual rainfall at each station. Rainfall intensity and annual rainfall data was used to plan soil and water conservation measures. Additional meteorological stations were established in 1992 at two of the project villages *viz.* at Titvi and Manhere. An automatic recording system has been used to record data since 1993. Designs of water conservation measures were then standardised, on the basis of the intensity of rainfall, obtained from the Manhere raingauge station.

From data collected at Manhere and Titvi stations and the other stations, it is seen that the variation in annual average rainfall is as much as 500mm to 1000mm over a distance of 3 to 7 km. The design of catchment area treatments, such as contour trenching, contour bunding, and drainage line treatments, like gabions and masonry checkdams is based on the peak intensity of rainfall. The published isohytal maps of IMD show that the project area falls under an intensity zone of 90 mm/hr. for a ten-year cycle. However, for a two-year cycle at the Manhere station, the intensity is only 46.5 mm/hr. The designs based on this intensity are almost half that of isohytal intensity. This realistic information was next used for standardising the designs of modules, which were tested in the area.

10.1.4 GEOHYDROLOGICAL STUDIES

In the first phase (1992) all the springs, open wells, bore wells and percolation tanks of the study area and the surrounding 11 villages were surveyed. Information regarding water table in monsoon, summer and winter, the profile of the wells and their yields was also obtained. A similar survey was repeated in 1995 and 1996 in the month of May to the see the impact of water resources development measures applied in the study area. Each location and elevation was determined using the Navpro 5000 (GPS) and a Pretel Altimeter. Later, in the implementation phase, detailed studies were carried out to determine the nature of rock, its water-holding capacity and availability of deep ground water. For this purpose, the soil gas levels were measured with a portable Rn 200 Radon Detector equipped with a 150V2 scintillation cell and potential sources of water, such as fractures and dykes were studied.

These analyses of observations helped to define guidelines to plan specific measures for developing water sources. This led to intensive water recharge measures, such as contour trenching, farm ponds, gabions with impervious ferrocement barriers, roof water harvesting systems, and the development of existing, potential water sources.

10.1.5 STUDY OF SOIL PROPERTIES

Various soil parameters were studied for an understanding of the nature of the soils for planning studies. Two types of tests were carried out.

1. Laboratory testing, which included the soil texture, porosity, bulk density, water content, electric conductivity and nutrient status.

2. Field testing included permeability tests and infiltration rates at different locations covering different types of soils. Soil profiles were also studied to understand the depth of top soil, nature of subsurface strata and its percolating and yielding properties.

The study results indicated poor yielding capacity of top soil layer in the main drainage channels / paddy fields and poor availability of water reservoir capacity of subsurface soils in the paddy areas. Based on this information, treatments such as infiltration of water by breaking the top soil layer, water recharge ponds and farm ponds were evolved and implemented. For testing soils in the field, equipment such as a field permeameter and tensiometers were used for obtaining saturated field permeability and recording field moisture levels respectively.

10.1.6 USE OF REMOTE SENSING / SATELLITE IMAGERIES

BAIF and the Space Application Centre, Ahmedabad, jointly studied satellite imageries of the project area. The imageries were integrated with topographic maps and cadastral level maps. The steps involved were data procurement, base map preparation, preliminary interpretations of imageries, field checks, final interpretations and final mapping. The outputs were a slope map, a hydrogeomorphological map, a forest density map, sub-watershed/drainage map, and suggested sites for water resources development, water resources and wasteland development sites for Manhere, Titvi and Ambevangan villages. Satellite imageries in the form of lineaments were studied, their interpretation on the ground was observed and plans to utilise them were finalised.

10.1.7 USE OF GIS

Geographic information systems were very useful during initial phases of the project. This technique was used to render tabulated data, available on the maps, so as to specify its location. Diverse data procured on various maps were next overlain to derive a specific utility map. For example, lineament features were overlain on the village level cadastral maps and drainage maps to locate and check ground features. All water sources, i.e. springs and wells of the area, were mapped with the help of a hand held GPS (Global Positioning System) to locate the latitude and longitude of a sample point. Updating of the information was carried out continuously for ready reference.

10.1.8 USE OF GEOLOGICAL / GROUND FEATURES

Two types of feature have been studied. One is the distribution of lineaments, received from the Satellite Application Centre in the form of a map. The other covers the visible ground features, such as exposed fractures and dykes, known to BAIF field staff and villagers. The cadastral maps with lineaments, overlain on them, were taken to the field and all such sites were observed to see the interpretation of these lines. Many of the lineaments were ridges and some had thick soil cover. Recharge methods were finalized on the basis of a clear understanding of these features. The ground features, which were known to the villagers, were studied with a view to utilising them as sources for water resource development. Geo-electrical method was used to find out the horizontal and vertical extents of the inferred fractures and dykes. Treatments to augment the water sources have been recommended after the study. One fracture was excavated in Ambevangan village up to 3m depth and an observation well was constructed. Water is now available there throughout the year. The upstream side of this fracture has been treated intensively by trenching, gully plugging and construction of a farm pond.

10.2 PILOT TESTING OF EXPERIMENTAL SOIL & WATER CONSERVATION AND UTILISATION MEASURES

The following interventions for conservation, development and utilisation of water resources have been tested on a pilot basis and standardised.

Appropriate use of traditional measures:

1. Gully plugging / stone bunding
2. Contour trenching / bunding
3. Recharge pits / ponds
4. Farm ponds
5. Well development and spring development
6. Masonry checkdam
7. Use of micro-irrigation techniques for efficient water utilisation
8. Creation of vegetation cover in catchment area

Innovative measures:

1. Gabion structure
2. Gabion structure with ferrocement barrier
3. Artificial recharge and utilisation of water from fracture
4. Roof water harvesting
5. Infiltration trenches / breaking top soil layer
6. Spring development
7. Underground barrier

10.3 STANDARDISATION OF PROTOCOLS FOR DATA COLLECTION / FIELD MEASURES

Protocols for various experimental measures / field interventions have been developed. The literature for these activities have been developed in the following forms:

1. Water table logging module
2. Field level rainfall measurement module
3. Roof water harvesting
4. Ferrocement gabion

10.4 IMPACT OF PILOT ACTIVITIES

The overall impact of the field interventions is increased water availability and improved awareness amongst the community about soil and water conservation techniques. The specific impacts of the measures, applied through the study on a pilot basis in the three villages and outlying areas, are given below.

10.4.1 SOIL CONSERVATION

The area has been treated on watershed basis. The upper reaches, which are mostly wastelands with slopes more than 30%, have been treated with contour trenching plantations, grass development and plugging of small gullies. An area of approximately 1000 ha has been treated with contour trenching. The estimated soil loss in this area before treatment was about 75-150 tonnes /ha per year. Due to this intervention (trenching), rainwater does not flow as surface runoff and hence the loss of soil is minimized. An annual soil loss of about 75000 - 150000 tonnes from an area of 1000 ha has been prevented. In the gullies of the upper and middle reaches, 6550 gully plugs, 75 dry stone bunds and 75 gabions were constructed. Visual observations on depth of soil, arrested by these measures, indicate that about 8000 tonnes, 11000 tonnes and 13000 tonnes of fertile soil have been conserved behind these structures. The total annual soil loss prevented as a result of these interventions is equivalent to a topsoil layer of 6 to 10mm thick, spread over the entire area.

10.4.2 WATER RECHARGING

Water recharge has been accelerated, due to water-arresting trenches (contour trenching) in the 1000 ha area. The annual average recharge is in the region of 10-19 million cubic meters (based on 4 years average annual rainfall at Titvi and Manhere villages). Apart from this measurable recharge, gully plugging, stone bunds, gabions, recharge pits and ponds also augment ground water flow. Altogether, 19 farm ponds were excavated. The ultimate effect of this was increased moisture in the downstream fields, which has enabled about 75 ha. of land to produce a second crop during the winter and about 300 ha additional land (formerly wasteland) to be brought under cultivation during the rainy season.

10.4.3 INCREASED WATER AVAILABILITY

Surface water-storage structures, subsurface source developments and roof water harvesting systems have increased water availability and promoted easy accessibility for drinking and agricultural uses for all the 494 households of the project area. Twenty-six households (5%) receive water at their doorsteps through roof water harvesting systems. Most of the households residing in the hamlets (about 10-20% of the total households) now have access to safe drinking water all year round, as a result of the development of 6 natural springs. About 73 thousand m^3 of water is now stored behind 14 permanent masonry checkdams and 3 ferrocement gabions. This water is used for drinking by the households, residing in the hamlets and, in the dry periods, by cattle as well. With normal rains, about 75 ha of land was brought under an assured second crop, due to increased soil moisture and surface water storage. The outcome is that water availability has been increased by about 750 L per day per capita in the drought period.

10.4.4 SKILLS DEVELOPMENT

Local youths acquired skills in all the water - and soil-conservation activities during the implementation phase of the project. About 25 youths were trained in ferrocement technology and masonry construction, 10-15 persons in each village in the technology of erecting gabions and about 8-10 women and men technicians in each village in the soil-conservation activities of contour trenching, bunding etc. Nursery and grafting techniques were also acquired by 4-5 youths in each village. Techniques of installing roof water harvesting systems, carrying out repairs to handpumps, construction of checkdams, soil and moisture conservation measures, etc. have been assimilated by many members of the villages.

As the programme was implemented through the involvement of the villagers, they also received an opportunity to develop rudimentary managerial skills and to develop their leadership qualities.

10.4.5 AWARENESS ABOUT CONJUNCTIVE USE OF WATER

Earlier, the degraded resources, lack of income-generatihg opportunities and lack of other infrastructure development had created a gloomy picture in the minds of the young. An additional impact of the collaboration is an increased level of motivation within the community. From their reactions it is apparent that they have realised the need and benefit of protecting their environment. Tribals, who benefit from interaction with nature, are sometimes not fully aware of environmental protection methods, Since various new techniques were introduced at different times and at different locations in the area, the dissemination of this knowledge was widespread and is not concentrated within any particular group. This has helped many people to learn and acquire new skills for the development of water resources.

Such demonstrations and experiments are giving communities greater exposure to modern technology, as well as knowledge for the development of eco-friendly environments in their villages. A positive attitude towards learning new things was witnessed, particularly amongst members of the younger generation.

10.4.6 COMMUNITY ATTITUDES

In each of the last two years (1994-95, 1995-96), the area received only 75 to 80 % of the annual rainfall within a narrow span of two months. As a result, the production of food crops was lower by about 30 to 40%. However, the area under cultivation was increased by 20%, so that the potential food scarcity was reduced. This also gave an opportunity for production of a surplus, to be sold at local markets in future years.

10.5 ORGANISATIONAL STRENGTHENING

BAIF Development Research Foundation is working in five states of India. The major programmes are land based, with water-resources development a core component of all activities. The considerable technical knowledge, acquired during the project will have positive implications for all other programmes undertaken by BAIF.

Specifically, the skills acquired by the BAIF staff in survey methodologies for developing water resources can be applied to any area. The techniques for water conservation, developed in the Deccan Trap area, will be tested and developed in other areas and agro-climatic conditions across India.

10.6 INDIRECT BENEFITS

Awareness, generated in the constructive use of the scare water resources, was demonstrated by development of kitchen gardens, fed by waste water. This has helped in maintaining sanitation around the houses. In this way, nutrition-rich food was made available to about 200 families with the help of kitchen gardens. Produce is available for about 8 to 10 months of each year. This activity is now accepted by the villagers, who have started developing kitchen gardens independently.

10.7 DEVELOPMENT OF REPLICABLE APPROACH

The protocols have been developed and tested in the Deccan Trap. Of these protocols, methodologies for recharging, conventional contour trenching and gully plugging are replicable in other situations. Protocols construction of gabion structures and ferrocement gabions can be used as low-cost technologies of soil and water conservation in hilly areas. Roof-water harvesting systems are applicable in areas of water scarcity. These systems are particularly useful in areas, where the villages receive drinking water, brought from external sources by tankers.

The literature prepared on these technologies will be distributed among NGOs and government organisations, involved in the field of water-resource management. Training sessions and workshops will be held at the national level to share the technologies and methodologies, developed during this study.

10.8 RECOMMENDATIONS

10.8.1 POLICY

- The Western Ghats form a large part of the Deccan Trap. This region has tremendous variation in climatic conditions, even over distances as small as 1 to 2 km. The planning of a water-resource development programme on a watershed basis needs factual, climatic data. This is possible only with the establishment of a network of meteorological stations.

In the transition zone of the Western Ghats, stations at distances of 5 km apart are necessary for the collection of realistic data. The proposed range is from the ridge to the existing **IMD meteorological stations on the eastern side**.

- Remote sensing interpretations, such as lineament maps, drainage maps, information about groundwater resources and the nature of subsurface strata, are very useful for facilitating micro-level planning of water-resource development. **Such interpretations should be made available to the agencies involved in this field.**

- The use of **Geographic Information Systems (GIS) should be promoted among all agencies working in development of water resources.** GIS is also useful in analysis and updates of field information.

10.8.2 TECHNOLOGY

- Water storage tanks should be installed near houses in areas, where water is scarce in summer. These tanks can be filled with water, brought by groups of households or by the hamlet as a whole. Alternately, rain water can be collected from the roofs of houses and stored during the rainy season for use in the scarcity period. **Ferrocement is a low-cost technology for use in the construction of water tanks for roof water harvesting systems.**

- Domestic water availability and **use of a storage facility for individual households or small groups of families (up to 5) is manageable in scarcity areas.** Systems, such as roof water harvesting, will be the best alternative in community water-supply schemes. Since these schemes are also suitable for remote areas, they **should be promoted at such locations.**

- In high-rainfall areas, the post-monsoon flows exist for 3 to 4 months. Instead of creating water-storage facilities on land, these **flows should be arrested in the *nallas* / gorges by series of small checkdams.**

- **A gabion with a ferrocement barrier is a good, low-cost alternative to conventional masonry or earthen checkdams.**

10.8.3 INDIGENOUS TECHNICAL KNOWLEDGE

- In projects on watershed development, local skills and know-how must be taken into account at the planning stage.

- Involvement of local community members with the appropriate skills will ensure quality in activities such as construction of checkdams, ferrocement structures, bunding, trenching, etc. Hence **local community members should be trained in advance in all such activities, identified** as intended project outputs.

10.8.4 REPLICATION OF RESEARCH RESULTS

The methodology of conjunctive water use is widely applicable in the Deccan Trap area. Some modifications would be necessary, however, to use it in other areas. **Studies should be undertaken in other areas to implement the methodologies, developed in the present study with suitable modifications.** This will be useful for future watershed development programmes in various regions of the country.

The needs assessment and baseline survey revealed major differences among the villages of Ambevangan, Manhere and Titvi, with regard the availability of water. The alphabetical listing of the villages, given above, was also the order, in which they were ranked at the start of the project, in terms of decreasing availability of water. Immediately prior to the 1997 monsoon, the villages ranked approximately equal in access to water, mainly derived from fractures and aquifers in weathered bedrock by seepage.

The long-term benefits to villagers, arising out of adoption of the project's strategy for water-resource management, included the following :

- There is year-round availability of water at some checkdams, gravity-flow systems, developed springs and dug wells. The water from springs tends to be used for domestic purposes only, while that from the other sources is put to agricultural, as well as domestic uses.
- Village women and older children now see a reduction in water-related hardships, imposed on them by tradition. As a result, many women work longer hours in the fields and thus contribute directly to increased, agricultural production. In addition, women make a bigger contribution to village committees.
- Villagers report a reduction in the incidence of skin diseases and other health problems, connected with water shortages, such as gastro-intestinal disorders. Increased attention to hygiene and sanitation on the part of the villagers is likely to have a beneficial impact on public health.
- The tribal and rural people have demonstrated personal motivation to improve and maintain water quality. This is seen, where women strain water through *sari* material to remove particulate matter. As well, farmers have sought instruction on the routine cleaning of dug wells. There is widespread interest in hygiene and sanitation.
- There are increases in employment opportunities in the villages, in part as a result of the additional land that has gone into agricultural use. This is directly related to the increased availability of water as soil moisture, in what was formerly wasteland. Men are under reduced pressure to work away from home.

- Villagers, who elect to work away from home, are able to do so as individuals with skills for sale. Their new skills are directly related to the vocational training, acquired at the demonstration sites for water-harvesting and - spreading techniques. Accordingly, the villagers face improved employment prospects.
- Villagers demonstrated initiative through discussion and planning of expanded use for the excess water, derived from the application of project technologies. This is particularly true of the farmers, working in outlying areas. They were interested in taking water from dug wells for irrigation purposes.
- The planning of new, agricultural enterprises by individuals and village cooperatives featured prominently in discussions with the villagers. An example of this type of micro-enterprise is the intention to introduce mechanised milling facilities. Groups of village women showed particular aptitude for this kind of thinking.
- The morale of villagers showed a progressive improvement throughout the project term. This was evidenced by more outgoing attitudes, new attention to personal appearance, and better upkeep of houses. The area has seen a number of new housing starts. The status of women has improved within each of the communities.

This list represents an attempt to group comments by the villagers on project impacts. The opinions of the tribal and rural people were obtained at village meetings and as the comments of individuals, working in the fields.

The project was successful. It provided the villagers of Ambevangan, Manhere and Titvi, as well as inhabitants of outlying areas, with an effective water-resources management strategy. The demonstration sites for appropriate water-harvesting technologies, introduced into the area, provided the tribal and rural people with a year-round water supply.

The tribal and rural people were involved in the design of the project. They contributed to the monitoring and evaluation of its results on a daily basis. They have the technical capability to sustain the project results, which they have taken over, along with the responsibility for maintenance. The technologies introduced are small-scale, cheap and easily replicated. The increased agricultural production will provide both the motivation and the sustaining resources, needed to operate and maintain the technologies.

All of the above factors indicate that the project results are sustainable. It is pertinent to note that the project was funded initially for three years beginning in April, 1992, and the project term was extended by a further year, without additional funding. The assessment of the effectiveness of project technologies took place more than a year after completion of the extended project term, prior to the onset of the 1997 monsoon.

Many water-supply projects fail, or appear to have failed, because the time frame for assessment of sustainability is too short. It is suggested that attention to socio-economic factors, such as the benefits to villagers, listed above, might yield indirect indicators of eventual project sustainability for a wide range of water-supply projects, operating over shorter terms.

◆◆◆◆

11: CONCLUDING REMARKS

1. The project, titled "Conjunctive Use of Water Resources in Deccan Trap, India", involved BAIF Development Research Foundation, Pune, India, and University of Windsor Earth Sciences, Ontario, Canada, working in partnership with the tribal and rural people of Akole Taluka, Maharashtra. The purpose was to provide the rural poor with a management strategy for acquiring a year-round water supply. The project, which ran from 1992-1996 was funded by the International Development Research Centre, Ottawa, Canada. The tribal and rural people participated in all stages of project design and implementation. A unique feature of the project was the important role of BAIF's field officers, who lived in the area and shared the daily hardships of the villages.

2. A needs assessment was carried out by BAIF in 1990. It had a focus on water use and the health of the villagers in Akole Taluka. The drinking water of the villagers mainly came from dug wells and springs, with more limited input from a few bore wells and ephemeral streams. In the summer months, most local water sources dried up. By tradition, the women and older children had the responsibility of locating and transporting water for domestic use. The transportation of water by tanker-truck from the Pravara River to some dug wells, as an initiative of local government, proved to be an erratic source. Lack of hygiene and sanitation, together with the general shortage of water in summer, were the cause of skin diseases and gastro-intestinal disorders.

3. Initially, observations were made on the hydro - geologic environment over a wider area of Akole Taluka. Then attention was focused on the specific water-supply needs of the villages of Ambevangan, Manhere and Titvi and farmers in outlying areas. Occupying the lowest rung of the social ladder, the villagers lived in conditions of extreme poverty. They owned bullocks, cows, goats and hens and practiced agriculture at a subsistence level of the production. In the *kharif* growing season (June to September), they grew rice, groundnuts, *ragi* and local grass. During the *rabi* season (October to January), their main crops were wheat and *gram*. However, the quality of the second crop was largely determined by the availability of soil moisture.

4. The tribal and rural people demonstrated good understanding of natural processes and responses at a local level. In their approach to agriculture, they aimed for reciprocity with nature. They created new land for cultivation by erecting barriers across streams to trap soil particles and organic material. They also returned nutrients to the soil, in the form of ashes from branches and leaves, burned on small areas of land. The knowledge system of the farmers also included a classification of land, based on soil type and appropriate crops. Indigenous knowledge with a substantive role in project activities included local awareness of botanical indicators

of shallow ground water and the relationship between terrain features and soil moisture.

5. Human resource development was a major component of capacity building in the framework of the project. BAIF field officers and programme coordinators were trained in basic field techniques of hydrology, hydrogeology, and geology, related to project activities. As well, selected personnel attended workshops on topics, pertinent to water-harvesting and -spreading. Institutional development took the form of additions of equipment at the head office, in support of the computer processing of field data. Decisions, as to the appropriateness of possible technologies for water conservation, were made at village meetings. Interested villagers received vocational training, necessary for the safe and effective introduction of these technologies at demonstration sites.

6. Weak monsoon rains and frequently related drought conditions in Akole Taluka in general are among the climatic anomalies, associated with El Nino-Southern Oscillation events. This relationship may be used as an approximate guide for the planning of water-conservation activities by government decision-makers. Major variation in monsoon rainfall was observed in the three partner villages, even during the wettest months of July and August. Work on the examination of runoff/rainfall ratios was initiated in 1994, using stage measurements from a check dam in a sub-basin at Manhere to estimate discharge. Surface outflow from the sub-basin appeared to be greater than or equal to inputs, because of the lag in time between upland additions and losses over the spillway of the check dam.

7. The discharge of ephemeral streams decreases through the post-monsoon season, approaching zero in the early, pre-monsoon months. Subsurface waters occur in the soil, weathered bedrock, and basalt lavas, which are characterized by variable and generally poor aquifer potential. Surface runoff prevails in many valley-floor settings, where low hydraulic conductivity of surface soils inhibits infiltration. Ground-water movement is localized in the weathered bedrock and at interruptions to the vertical and lateral continuity of the lavas. Pervasive fractures and basalt dikes in the bedrock show a preferred orientation that is approximately northwestward. These and elongate bodies of modern valley fill were mapped from satellite imagery as lineaments, prior to more detailed field study.

8. Data on surface runoff, seepage, and anisotropy of subsurface flow were integrated with indigenous knowledge of shallow ground water in the design of appropriate water-conservation technologies. This was done to minimize the surface flow of monsoon waters out of the area to lower elevations. Technologies, some of them several millennia old, were transferred from other dryland regions. Soil ridges and trenches were configured on the terraced hillslopes to divert runoff underground. Artificial recharge, deepening of dug wells, and workovers of bore wells improved water-well yields. Checkdams were constructed to trap surface runoff and seepage

waters. Some spring discharges were diverted to storage tanks. The rain, falling on the roofs of houses, was collected and stored in tanks.

9. Vocational training at the village level was facilitated by collaboration with the tribal and rural people on the installation of demonstration sites for the technologies in water conservation, considered appropriate. In addition to promoting wider adoption of project technologies, this also provided the villagers with marketable skills, related to water supply. Special attention was given to the measurement and analysis of rainfall data as essential inputs into the design of conservation measures. Individual households were instructed in the techniques of roof-water harvesting for the provision of drinking water. Villagers were shown how to construct drystone gabions, using chainlink and barriers of ferrocement. Compliance with Indian standards was emphasized, wherever possible.

10. The water-resource management strategy, arising out of the project, integrates diverse levels of technology, including indigenous knowledge of botanical indicators for shallow ground water; field and laboratory techniques in hydrology, hydrogeology, and geology; and the use of Earth satellites in orbit for precise field location and the mapping and analysis of ground features. Demonstration sites for appropriate technologies of water-harvesting and -spreading, with supporting soil-conservation measures, yielded sufficient water to satisfy the domestic needs of the villagers and brought additional benefits to agricultural practice and livestock management. The tribal and rural people now have marketable skills, related to project activities. They face the future with a new sense of purpose.

◆◆◆◆

SELECTED REFERENCES

Agarwal, S. 1994. *Geochemistry* and *Geohydrology of the Deccan Volcanics of Akole Taluka, Ahmednagar District, Maharashtra State, India.* Unpublished M. Sc. Thesis, University of Windsor, 132 pp.

Asher-Bolinder, S., Owen, D.E., and Schumann, R.R., 1991. A preliminary evaluation of environmental factors influencing day-to-day and seasonal soil-gas radon concentrations, pp. 23-31, *in* Field Studies of Radon in Rocks, Soils, and Water. *United States Geological Survey, Bulletin 1971.*

BAIF Development Research Foundation 1994. *Community Based Research, unpublished Akole report,* BAIF, Dr. Manibhai Desai Nagar, Warje, Pune-29.

Ball , D.F., and Herbert, R., 1992. The use of performance of collector wells within the regolith aquifer of Sri Lanka. *Ground Water* v. 30, pp. 683-689.

Barker, J.A., and Herbert, R., 1989. Nomograms for the analysis of recovery tests on large-diameter wells. *Quarterly Journal of Engineering Geology,* v. 22, pp. 151-158.

Beane, J.E., Turner, C.A., Hooper, P.R., Subbarao, K.V., and Walsh, J.N., 1989. Stratigraphy, composition and form of the Deccan basalts, Western Ghats, India, *Bulletin of Volcanology,* v. 48, pp. 61-83.

Bombay Government, 1884. *Gazetteer of the Bombay Presidency, Volume XVII,* Ahmadnagar. Bombay, Government Central Press.

Bureau of Indian Standards, 1992. *(Indian Standard 4849), Meteorology Rain measures - Specifications, New Delhi, India.*

Bureau of Indian Standards, 1983. *(Indian Standard 4986), Manual Rainfall measurement - Specifications, New Delhi, India.*

Cannon, H.L., 1971. The use of plant indicators in ground water surveys, geologic mapping, and mineral prospecting. *Taxon,* v. 20, pp. 227-256.

Chandrashekar, H., Chandrashekarmath, S.S., and Ganachari, S.N., 1976. Groundwater fluctuations and calculation of effective porosity of laterite and effective fissure porosity of the basalt of the Karanja basin, Karnataka, India. *Journal of Geological Society of India,* v. 17, pp. 117-122.

Deolankar, S.B., and Kulkarni, H.C., 1985. Evaluation of transmissivity of Deccan basalts of Maharashtra, India, using aquifer response from large diameter dug wells, pp. 622-630, in: *Proceedings of International Associationof Hydrological Sciences Symposium, Hydrogeology of Rocks of Low Permeability, Part 2.*

Das, B.M., 1998. Principles of Geotechnical Engineering (Fourth Edition). Boston, PWS Publishing Company, 712 pp.

Deshmukh, S.S., and Sehgal, M.N., 1988. Mafic dyke swarms in Deccan volcanic province of Madhya Pradesh and Maharashtra, pp. 323-340, inSubbarao, K.V. (Editor), *Deccan Flood Basalts,Geological Society of India, Memoir 10.*

Elrick, D.E, and Reynolds, W.D., 1992. Methods for analyzing constant-head well permeameter data. *Journal of American Soil Science Society,* v. 56, pp. 320-323.

Fletcher, W.M., 1886. Papers Relating to the Revision of the Rates of Assessment on the Expiration of the First Settlement into the 50 Villages of the Akola Taluka of the Ahmednagar Collectorate. *Selections from the Records of the Bombay Government, No. CLXXXIV,* New Series.

Fletcher, W.M., 1888. Papers Relating to the Revision Survey Settlement of 102 Dangi Villages of the Akola Taluka of the Ahmednagar Collectorate. *Selections from the Records of the Bombay Government, No. CCXVI, New Series.*

Freeze, R.A., and Cherry, J.A., 1979. *Groundwater.* New Jersey, Prentice-Hall, 604 pp.

Gregory, K.J., and Walling, D.E., 1973. *Drainage Basin Form and Process: A Geomorphological Approach.* London, Edward Arnold.

Hanson, G., and Nilsson, A., 1986. Ground-water dams for rural water supplies in developing countries. *Ground Water,* v. 24, pp. 497-506.

Hey, N.H., 1916. Papers Relating to the Second Revision Settlement of the Akola Taluka of the Ahmednagar District. *Selections from the Records of the Bombay Government, No. DLXXIII,* New Series.

Katyal, J.C. Singh, R.P. Sharma, Shriniwas, Das, S.K., Padmanabhan, M.V. and Mishra, P.K., 1995. Field manual on Watershed Management, Central Research *Institute for Dryland Agriculture, Hyderabad, India,* pp-223.

Khadri, S.F.R., Subbarao, K.V., Hooper, P.R., and Walsh, J.N., 1988. Stratigraphy of the Thakurvadi Formation, Western Deccan Basalt Province, India, pp. 284-301, in Subbarao, K.V.(Editor), *Deccan Flood Basalts, Geological Society of India, Memoir 10.*

Limaye, D.G., and Limaye, S.D., 1985. Manifestation of ground water statics in thin and low permeability basaltic aquifer in India, pp. 729-734, *in: Proceedings of International Association of Hydrological Sciences Symposium, Hydrogeology of Rocks of Low Permeability, Part 2.*

MacDonald, M.L., 1994. *A Study of Zeolites in the Kalsubai Subgroup Deccan Basalts, Maharashtra State, India.* Unpublished B. Sc. Thesis, University of Windsor, 38 pp.

Meinzer, O.E., 1927. Plants as Indicators of Ground Water. *United States Geological Survey Water-Supply Paper 577,* 94 pp.

Michel, J., 1990. Relationship of radium and radon with geological formations, pp. 83-95, in Cothern, C.R., and Rebers, P.A. (Editors), *Radon, Radium and Uranium in Drinking Water.* Chelsea, Lewis Publishers. Murty,

Murty, K.S. 1987. Varahamihira, the earliest hydrogeologist. Water for Future : Hydrology in perspective *(Proceedings of the Rome Symposium April, 1987). IAHS Publ. No. 164,* pp. 11-15.

Nessler, U., 1980. Ancient techniques and modern arid zone agriculture. *Kidma: Israel Journal of Development,*v. 5, pp. 3-7.

Philander, S.G., 1990. *El Nino, La Nina and the Southern Oscillation* New York,. Academic Press, Inc., 293 pp.

Powar, K.B., 1981. Lineament fabric and dyke pattern in the western part of the Deccan Volcanic Province, pp. 45-57, inSubbarao, K.V., and Sukheswala, R.N. (Editors), *Deccan Volcanism and Related Provinces in Other Parts of the World. Geological Society of India, Memoir 3.*

Reynolds, W.D., and Elrick, D.E., 1986. A method for simultaneous in situ measurement in the vadose zone of field-saturated hydraulic conductivity, sorptivity and the conductivity-pressure head relationship. *Groundwater Monitoring Review,* v. 6, pp. 84-95.

Reynolds, W.D., and Elrick, D.E., 1987. A laboratory and numerical assessment of the Guelph permeameter method. *Soil Science,*v. 144, pp. 282-299.

Subbarao, K.V., and Hooper, P.R., 1988. Reconnaissance map of the Deccan Basalt Group in the Western Ghats, India. *In*: Subbarao, K.V. (Editor), *Deccan Flood Basalts, Geological Society of India, Memoir 10* (enclosure).

Tagare, G. V., 1992. Water exploration in ancient India. *The Decan Georapher* vol. 30, no. 2, pp. 43-48.

Tagare, Thigale, S.S., 1979. Species of Eugeniaas groundwater iindicator plant in Western Ghats of Maharashtra. *Science and Culture,* v. 45, pp. 39-40.

Thigale, S.S., and Sen, M., 1982. Significance of bottomland flora in hydrogeological investigation, pp. II-1 to II-5, in: *Proceedings of International Symposium on Hydrological Aspects of Mountainous Watersheds, November 4-6, 1982.*

Thigale, S.S., and Tavate, P.R., 1979. Prosopis spicigeraLinn.: a phreatophyte in the Deccan Trap region of western Maharashtra. *Bulletin of Earth Sciences,* v. 7, pp. 49-50.

Tytler, C.E.F., 1848. First Survey and Settlement of the Akola Dangs, 1848, pp. 58-70, *in* Fletcher, W.M., 1888. Papers Relating to the Revision Survey Settlement of 102 Dangi Villages of the Akola Taluka of the Ahmednagar Collectorate. *Selections from the Records of the Bombay Government,No. CCXVI, New Series.*

Whetton, P., and Rutherford, I., 1994. Historical ENSO teleconnections in the eastern hemisphere. *Climatic Change,* v. 28, pp. 221-253.

Yurtsever, Y., 1975. Worldwide survey of stable isotopes in precipitation. *International Atomic Energy Authority, Section on Isotope Hydrology, Report (November, 1975),* 40 pp.

◆◆◆◆

ANNEXURES

ANNEXURE - 1

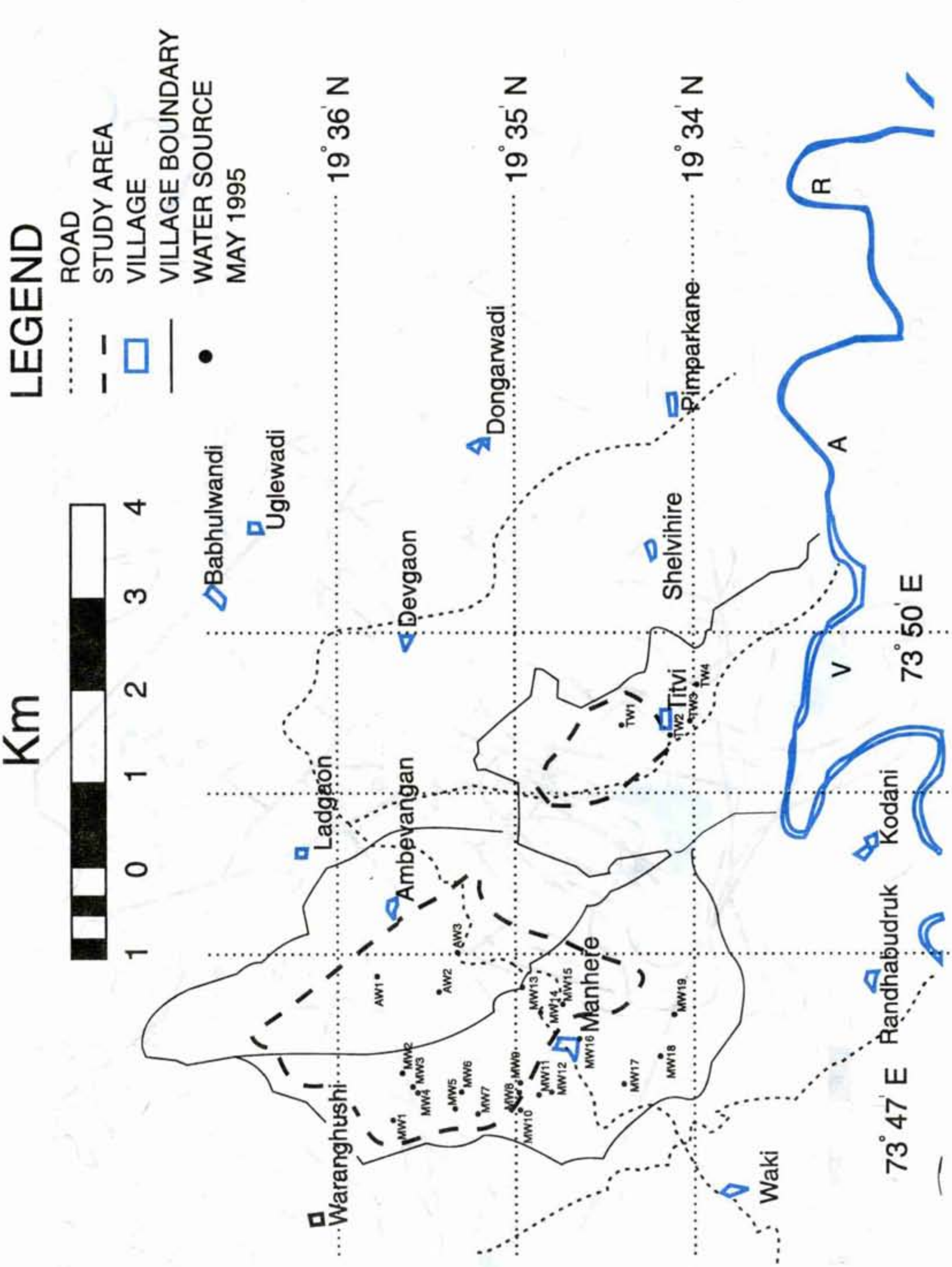
WELL INVENTORY

Water Sources	Description and Location	Seepage Evidence May 1995	Seepage Evidence May 1996
MW1 Manhere Maruti Bhau Gabhale	Private excavation to the basalt in the main *nalla*. This is northernmost water source in the study area. 19⁰ 35. 70N73⁰ 46.95E and 826m.	Yes-locals estimated a 30 cm overnight recovery. Seepage at 824 m.	15 cm overnight recovery. Seepage level at 824 m.
MW2 Manhere Lalu Rama Zambade	Private, lined, large diameter dug well in the far eastern *nalla* : 19⁰35.65N73⁰47.24E and 830m.	Unknown-water level at 823 m.	Unknown-water level at 823m.
MW3 Manhere Dattu Rama Zambade	Private blast hole in the far eastern *nalla*. 19⁰35.58N73⁰47.16E and 819m.	Yes- very small amount. Seepage at 815 m.	100 cm water depth
MW4 Manhere Dattu Rama Zambage	Private blast hole in the far eastern *nalla* and just west of a local hut : 19⁰35.56N73⁰47.13E and 814m.	Yes - very small amount. Seepage at 810 m.	
MW5 Manhere Chandar Laxman Zambade	Private blast hole at the *nalla* junction. Lining for the top 1.5m and a flow contact visible : 19⁰35.36N73⁰47.03E and 786m.	Unknown - but water level decreased slowly during the pre-monsoon season. Water level at 782-83 m.	
MW6 Manhere Poona Chima Zambade	Private dug well into basalt on the eastern hillside. Exhibiting a dyke (N35 W) approx. 15cm in width. Well is lined near the surface : 19⁰35.31N73⁰47.13E and 840m.	Yes-inflow evident through the dyke on the downslope side. possibly return flow of spilled surface water. Water level at 835m.	60 cm water depth
MW7 Manhere Sakharam Chima Zambade	Private, lined well into basalt in the main *nalla* : 19⁰35.23N73⁰.46.98E and 780m.	Unknown-but water level decreased slowly during the pre-monsoon season. Water level at 774 m.	

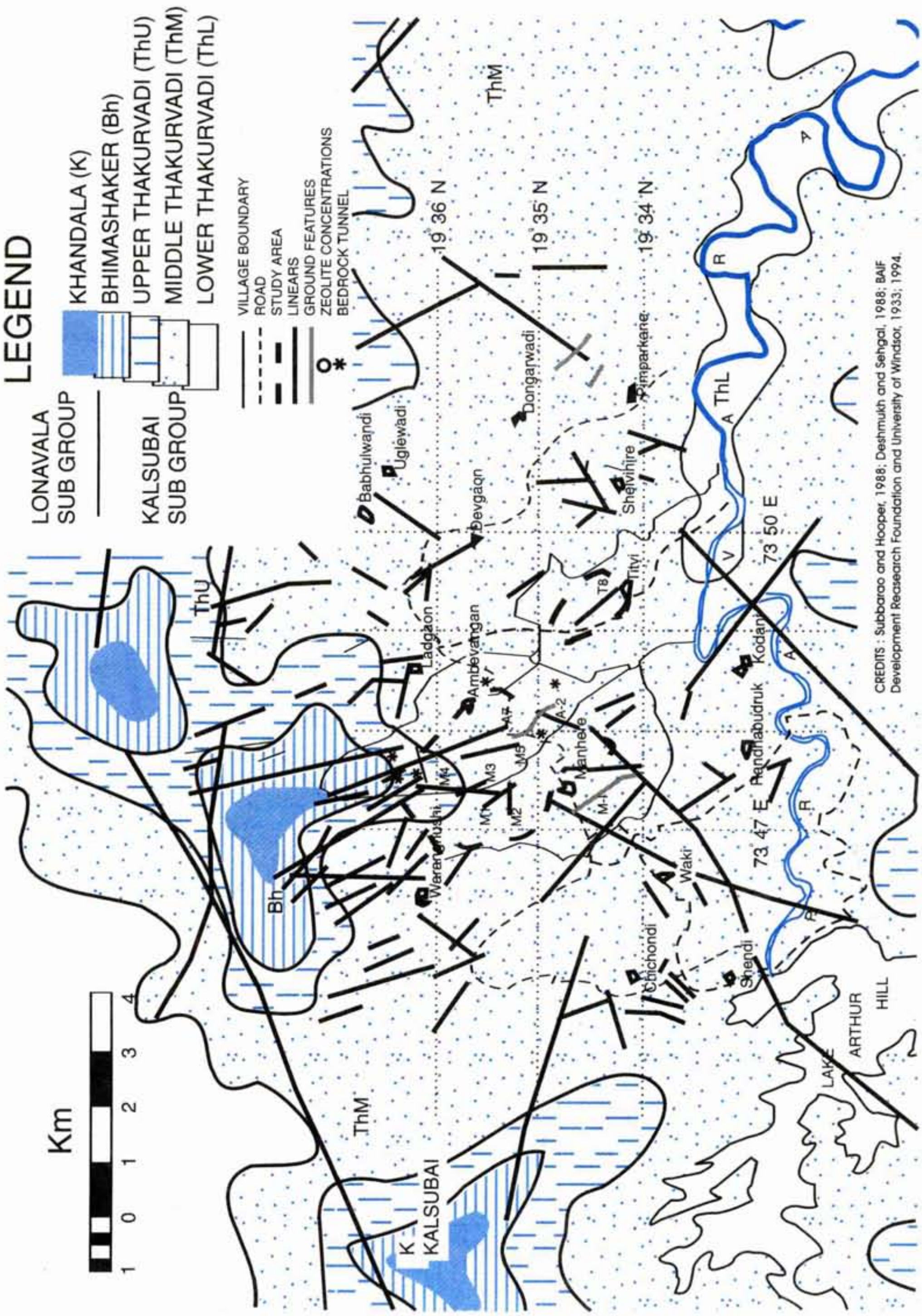
Water Sources	Description and Location	Seepage Evidence May 1995	Seepage Evidence May 1996
MW8 Manhere Ramchandra Budha Zambade	Private blast hole on the eastern edge of the main *nalla*. Vertical zone of weathered rock is visible in the side of the hole : 19⁰34.99N73⁰47.13E and 771m.	Yes-locals estimated a slight overnite recovery. Water level at 767 m.	Slight overnight recovery.
MW9 Mahnere Sampat Govinda Zambade	Two private blast holes on the eastern edge of the main *nalla*. Floor contact visible : 19⁰34.98N73⁰.47-18E and 772m.	Yes-inflow evident at the flow contact in both holes. Locals estimated a 50 cm overnight recovery/ Seepage at 771 m.	
MW10 Manhere Ravaji Gopal Gabhale	Small excavation on the western edge of the main *nalla*. Appears to be at a flow contact : 19⁰34.98N73⁰47.02E and 772m.	Yes-locals estimated a 20 cm overnight recovery. Seepage at 771m.	
MW11 Manhere Maruti Dagadu Gabhale	Private, large diameter blast hole in the main *nalla*. Vertical zone of weathered rock is visible in the hole on bearing (N45 W): 19⁰34.88N73⁰47.12E and 764m.	Yes- locals estimated a 4 m recovery within a week. Water level at 760m.	30 cm water depth.
MW12 Manhere Bhiva Kisan Gabhale	Private, relatively deep, lined well in the main *nalla*: 19⁰34.82N73⁰47.13E and 761m.	Yes- locals estimated a 30 cm Overnight recovery. Seepage at 754 M	15 cm water depth
MW13 Manhere Public Well	Large, roadside, community well in the main *nalla*: well : 19⁰34.87N73⁰47.62N and 773m.	Yes-locals estimated estimated a 30 cm Overnight recovery. Water level at 765m.	15 cm overnight
MW14 Manhere Public Well	Small, community well southeast of the Gram Panchyat well: 19⁰34.83N73⁰47.62N and 772m.	Unknown-water table at 768 m.	30 cm overnight recovery.
MW15 Manhere Mahadu Gopala Ghorpade	Private blast hole downvalley from the two community wells: (MW 13&14) 19⁰344.75N73⁰47.67N and 767m.	Unknown - water table at 766m.	30 cm overnight recovery.
MW16 Manhere	Small (2m diameter), community well just south of the village: 19⁰34.65N73⁰47.47N and 761m.	Yes-inflow evident at a horizontal contact. Seepage at 758 m.	
MW17 Manhere Tukaram Bhau Gabhale	Large, Private, lined well on the Western edge of the main *nalla*: 19⁰34.38N73⁰47.17E and 745m.	Unknown-water level at 739 m	15 cm water depth.

Water Sources	Description and Location	Seepage Evidence May 1995	Seepage Evidence May 1996
MW18 Manhere Tukaram Bhau Gabhale	Large, private, lined well on the northeastern edge of the main *nalla*. Vertical weak zone suggested by extended lining on opposite sides of the well. Hydro lines pass directly over this well. 19°34.19N73°47.36E and 731 m.	Unknown-locals claimed yes. Water level at 722-23 m.	
MW19 Manhere Ravaji Gopal Gabhale	Small private blast hole on the northeastern hillside of the main *nalla*. This blast hole is just south of a dirt road that crosses the main *nalla* : 19°34.12N73°47.63E and 721 m.	Yes-water level appeared to fluctuate from day to day. Water level at 719 m.	2.5 m of water depth.
AW1 Ambevangan Tulsa Dhondu Khetade	Private excavation at a relatively deep soil and murum pocket in the main *nalla* : 19°35.79N73°47.85E and 789m.	Yes-locals estimated 50 to 60 cm. overnite recovery. Seepage at 782-83 m.	
AW2 Ambevangan Ganpat Laxman Dhande	Private blast hole at the base of western slope of the western *nalla* : 19°35.44N73°474.74E and 760 m.	Unknown - water level at 755 m	
AW3 Ambevangan Keli Spring	Roadside community spring (*Kelly* spring) in the main *nalla*: 19°35.79N73°4785E and 789m.	Yes-very small amount of Seepage at 749 m.	No seepage
TW1 Titvi Public Well	Small, lined, community wll in the lowest paddy field of the *nalla* : 19°34.42N73°49.42E and 706m.	Unknown-water level at 703 m.	30 cm water depth.
TW2 Titvi Public Well	Deep, community well in the southeast corner of the village. Near surface portions is lined 19°34.13N73°49.44E and 744 m.	Yes-locals estimated a 40L overnight recovery. Seepage from a vertical joint at 741 m.	
TW3 Titvi Harishandra Shahkar Mundhe	Private blast hole south of the village 19°34.04N73°49-46E and 732m.	Unknown-owner claimed that horizontal seepage occurred at 726m. Water level at 728m.	2.75 m water depth.
TW4 Titvi Public Well	Square, community well southeast of the village. An *Umbar* tree is growing from the inside of the well lining: 19°34.00N73°49.67E and 706m.	Yes-locals estimated a 100 Liter overnite recovery. Seepage at 696m.	30 cm water depth.

LOCATION MAP OF WELL INVENTORY SITES



BEDROCK GEOLOGICAL MAP



Soil Parameters

3A Field Moisture, Porosity And Bulk Density

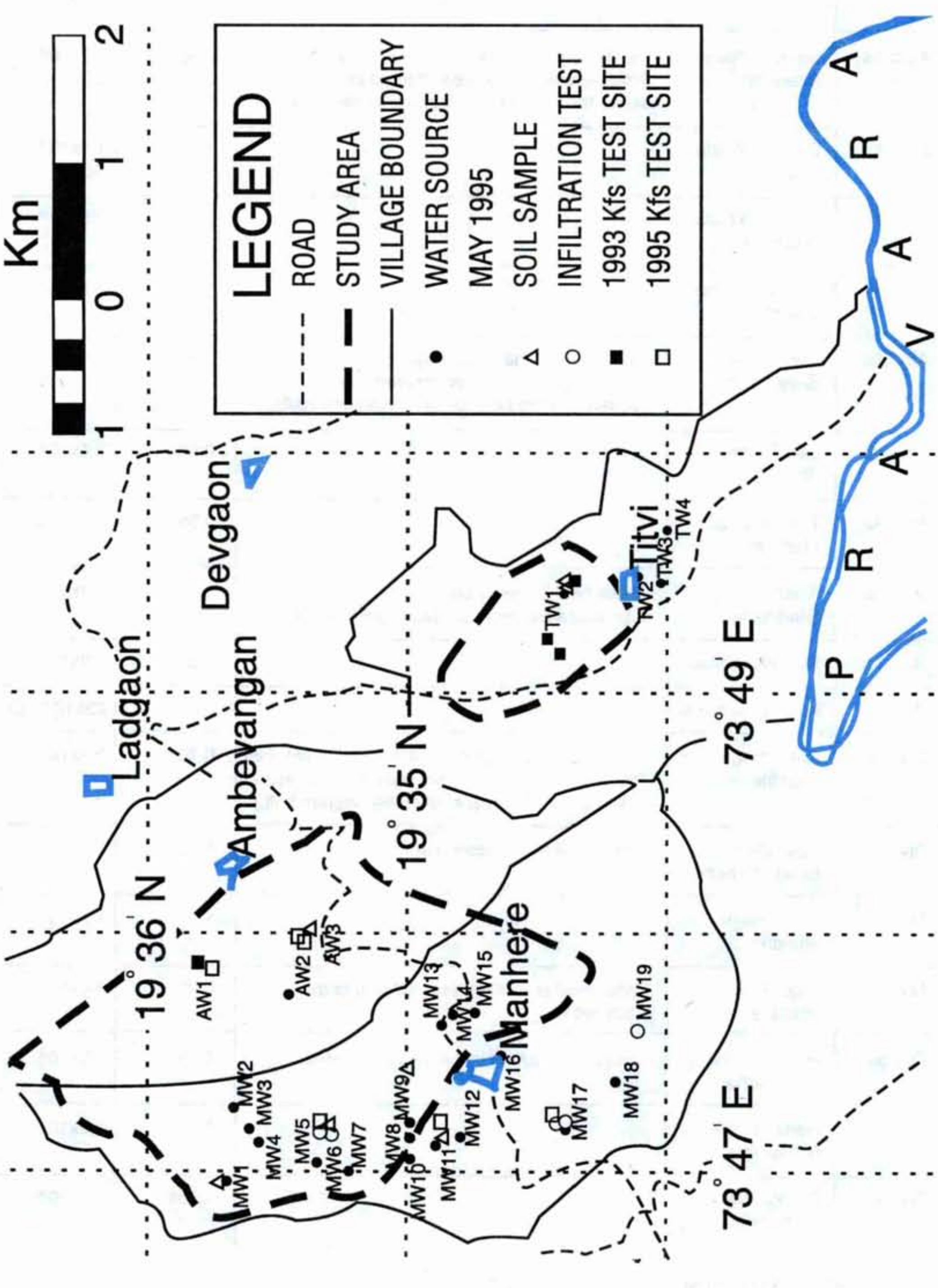
Sample	Depth(m)	Field moisture (% soil vol.)	Proposity (% soil vol.)	Bulk Density (g/cm3)
Titvi-1:t1-.2	0.2	35.9	44.3	1.26
Titvi-1:t1-.4	0.4	41.8	44.3	1.34
Titvi-1:t1-.6	0.6	38.1	46.1	1.22
Titvi-1:t1-.8	0.8	47.7	50.1	1.24
Titvi-1:t1-.1.0	1.0	43.1	47.6	1.28
Titvi-11:t2-.2	0.2	48.1	50.3	1.32
Titvi-1:t2-.6	0.4	46.5	48.2	1.63
Titvi-1:t2-.8	0.6	43.5	48.1	1.27
Titvi-1:t2-.1.0	0.8	41.7	50.8	1.17
Titvi-3	1.0	45.2	47.0	1.37
Titvi-3	0.35-0.4	37.6	47.8	1.16
Titvi-3	1.0-1.05	47.8	52.6	1.34
Titvi-3	1.5-1.55	23.2	39.2	1.52
Amb-1	0.35-0.4	44.4	52.6	1.42
Amb-1	1.0-1.05	40.9	48.9	1.38
Amb-2	0.35-0.4			
Amb-4	1.4-1.45			
Man-1	0.8-0.85			
Man-1	0.95-1.0			

Note : Titvi-1 core samples were collected horizontally from two walls of a soil pit.

3B SOIL TEXTURE

Sample	Description and Location	Collection date	Depth (m)	Fine Gravel and sand%	Silt %	Clay%	Texture
Amb-P1	Paddy field: second above the *kelly* spring	1995	0.2	37	61	2	Silt loam
Amb-KS	Paddy field: immediately above the *kelly* spring 19⁰.35.39'N 73⁰ 47.99'E	1995	0.2	36	63	1	Silt loam
Amb-4	Paddy field: third above *kelly* spring 19 ⁰35.39'N 73⁰ 47.99'E	1993	1.4	13	86	1	Silt
Amb-TENS	Paddy field:third above the *kelly* spring	1995	0.4	44	55	1	Silt loam
Amb-1P	Infiltration pit on the western hillside of the *kelly* spring *nalla* West of Amb-4's location	1995	0.3	43	55	2	Silt loam
Man-FW	Paddy field:Main *nalla* of Manhere near a large diameter blast hole 19⁰34.88'N 73⁰.47.12'E	1995	0.2	21	76	3	Silt loam
Man-1B	Field immediately above the sub-surface dam: 19 ⁰35.31'N73⁰ 46.95'E	1993	0.8	62	37	1	Sandy loam
Man-DW	Terraced ledge on the eastern hillside of the main *nalla* directly : 19 35.31'N73 47.13'E	1995	0.2	34	65	1	Silt loam
Man-G	Storage area behind the gabion structure in upper reaches of the main *nalla*: 19 ⁰35.91'N 73⁰ 46.95'E	1995	0.2	69	30	1	Sandy Loam

Location Of Water Sources, Soil Samples, Infiltration Tests & Kfs Tests



Field Permeameter Tests

5A Field Permeameter Tests For 1993

Test site	Land owner	Description	Depth (m)	Kfs (m/s)
Amb-1a	Devram Yeshy Dhandhe	Paddy field in the eastern *nalla* of the Ambevengan study area situated immediately above the highest well (spring) in the *nalla*.	0.38	$9.7x10^{-8}$ SEA
Amb-1b	Devram Yeshu Dhandhe		1.05	$1.1x10^{-7}$ SEA
Amb-1c	Devram Yeshu Dhandhe		2.04	$9.6x10^{-8}$
Amb-d	Devram Yeshu Dhandhe		2.24	$1.7x10^{-7}$
Amb-2a	Lalu Rama Bhojane	Paddy field in the middle *nalla* of the Ambevengan study area located 2 fields upstream of the junction of the western *nalla*.	0.4	$6.1x10^{-3}$
Amb-2b	Lalu Rama Bhojane		0.85	$7.6x10^{-8}$
Amb-4a	Tukarama S. Khatade		0.35	$7.5x10^{-8}$
Man-1a	Kisan Ghabhade	Paddy field immediately above the subsurface barrier in the Manhere study area.	0.35	$1.4x10^{-7}$
Man-1b	Kisan Ghabhade		0.85	$1.9x10^{-6}$
Man-c	Kisan Ghabhade		1.0	$23x10^{-6}$ SEA
Titvi-1a	Kalu Bhaga Mundhe	Paddy field the main *nalla* of the Titvi study area. The field immediately down vally of the highest well in the *nalla*. (Test hole in the western half.)	0.75	$2.3x10^{-8}$
Titvi-1b	Sakharam Bhaga Mundhe	Test hole in the eastern half.	0.75	$1.6x10^{-8}$
Titvi-1c	Kalu Bhaga Mundhe		1.4#	$1.3x10^{-7}$
Titvi-2	Kalu Gaunga Mundhe	Paddy field on the western hill side of the Titvi study area.	0.75	$3.8x10^{-7}$
Titvi-3a	Ramchandra N. Mundhe	Lowest paddy field in the Titvi study area.	0.35	$2.0x10^{-8}$
Titvi-3b	Ramchandra N. Mundhe		1.0	$2.0x10^{-7}$ SEA
Titvi-3c	Ramchandra N. Mundhe		1.55#	$4.3x10^{-8}$

#-test hole with rock bottom SEA-simultaneous equations approach

5B FIELD PERMEAMETER TESTS FOR 1995

Test site	Description and Location	Depth (m)	K_{fs} (m/s)
Amb-sp	Soil pocket in the eastern *nalla* of the Ambevangan study area situated adjacent a deep (6m) spring in an earth hole : 19°15.79'N 71 17.85'E	0.55	$9.2x10^{-7}$
Amb-Spb	Paddy field immediately south of the above mentioned earth hole.	0.53	$1.3x10^{-6}$ SEA
Amb-hill1 * Amb-1p	Infiltration pit on the western hillside of the *kelly* spring nalla. Three paddy fields north of the road:	0.23 19°35.39'N	$3.5x10^{-6}$ SEA 73°47.99'E
Amb-hill2	Infiltration on the western hillside of the *kelly* spring *nalla*. Next terraced level above the previous location	0.23	$3.8x10^{-6}$
Man-hill1 * Man-DW	Terraced ledge on the eastern hillside of the main *nalla* directly above the dyke well: 19°35.31'N 73°47.13'E	0.26	$7.0x10^{-6}$
Man-hill2	Same as above	0.32	$4.9x10^{-6}$
Man-mur1	Weathered basalt in the main *nalla* of Manhere. One paddy field east of a large diameter balst hole	0.2	$2.4x10^{-6}$ SEA#
Man-mur2	Weathered basalt on western edge of the main *nalla* in Manhere. 19°34.98'N 73°47.02'	0.2	$2.9x10^{-6}$ SEA#
Man-chan 1	Soil cover on the eastern hillside of the main *nalla* in Manhere and south of the village. 19°34.40'N 73°47.18'E	0.26	$8.7x10^{-7}$ SEA
Man-chan2	Same as above	0.53	$1.4x10^{-6}$ SEA#
Man-chan3	Same as above	0.2	$1.4x10^{-6}$

- test hole in or on weathered basalt (murum)

SEA - simultaneous equitations approach

* soil sample analyzed

ANNEXURE - 6

ELECTRICAL CONDUCTIVITY MEASUREMENTS FOR 1993

Village	Site Description	Conductivity (μ/cm)
Titvi	Community dugwell located in the lowest paddy field (Titvi-3) of the study area.	260 *
Titvi	Rivulet water flowing across the lowest paddy field (Titvi-3) of the study area.	270 *
Titvi	Rivulet water emerging from the bottom of the stone bund below the lowest paddy field (Titvi-3) of the study area.	250 *
Titvi	Rivulet water of the main *nalla* immediately upstream of the Devgaon junction.	225 *
Titvi	Private blast hole on the south side of the main nalla 6 fields upstream from the community well. (owned by Nana Q. Mundhe)	240 *
Titvi	Private dugwell located in the main *nalla*. This well is the highest in the main *nalla*. (owned by Kalu Bhaga Mandhe)	240 *
Titvi	Private blast hole on the north-eastern ridge. Water drainage is easterly towards Devgaon *nalla*. (owned by Sakharam B. Mundhe)	190 * 210 * (inflow)
Titvi	Private dugwell on the north-eastern ridge. The well is located at the top of a step east facing gully. (onwed by Kisan B. Mundhe)	220 *
Titvi	Community dugwell on the north-eastern ridge.	190 *
Titvi	Private dugwell in a small valley on the western side of the main *nalla* (6 paddy fields away). (owned by Jamana S. Mundhe)	210 *
Titvi	Private dugwell (shallow pit) on the western side of the main *nalla*. (owned by Jamana S. Mundhe)	200 *
Titvi	Community well on the hilltop adjacent to the village.	170 *
Ambevangan	Rivulet water flowering across the paddy field immediately above the *kelly* spring (road)	310 *
Ambevangan	Private well (developed spring) in the main eastern *nalla*. Located 16 paddy fields upstream of the kelly spring. (owned by Ganpat L. Dhandhe)	300 * 290 & 315 (inflows)
Ambevangan	Rivulet water flowering across a paddy field (Amb-2) in the middle *nalla* located two fields above the junction of the western *nallas*.	270
Ambevangan	Rivulet water from the western *nalla* immediately above the junction with the middle *nalla*.	280 *
Ambevangan	Private dugwell in the paddy field of the western nalla located immediately upstream of the junction with the middle *nalla*. (owned by Shivrama S. Ghadhe)	240 *
Ambevangan	Private spring on the western ridge close to the village boundary. (owned by Maruti G. Gabhale)	240 *
Manhere	Private dugwell in the main *nalla* near the end of the dirt road. (owned by Maruti G. Gabhale)	270 *

Village	Site Description	Conductivity (m/cm)
Manhere	Private dugwell in the far eastern *nalla* at the area with gour wells. This well is located in a deep soil pocket on the western side of the field (owned by Bundha D. Zambade)	270 *
Manhere	Private dugwell in the far eastern *nalla* at the area with four wells. This well is located in the middle of the four wells. (owned by Sakharam C. Zambade)	270 *
Manhere	Rivulet water junction in the main *nalla* to the west of the village.	170 * & 260 (West & East)
Manhere	Community bored well in the main *nalla* (above the road) to the west of the village.	240 *
Manhere	Private blast hole to the west of the village directly north of the ceremonial house on the road's edge.	290 *

* - Water sample collected.

SURFACE INFILTRATION TEST-FOR 1995

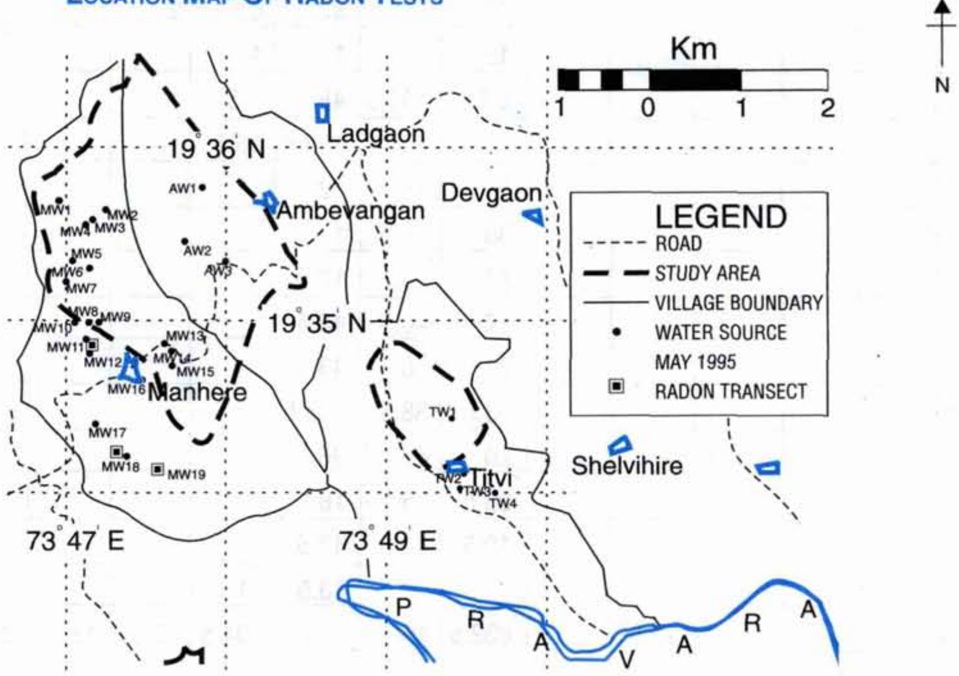
Test site	Description and location	Size	Infiltration Rate (m/s)
Man-paddy (Soil surface	Paddy field south of village in the main *nalla*: 10034.12'N 73047.63'E	Kined 20x20 cm	Test#1:1.7X10^{-5} Test#2:1.48x10^{-5}
Man-hill-s (soil)	Terraced hillside on the eastern slopes of the main *nalla* and adjacent the dike well: 19°35.31'N 73°47.13'E	Lined 20x20 cm	Test#1:2.19x10^{-5} Test#2:1.4x10^{-5} Test#3:1.1x10^{-5}
Man-hill-m (murum surface)	See above,	Kined 21x21 cm	Test#1:7.57x10^{-5} Test#2:3.78x10^{-5} Test#3:2.7x10^{-5}
Man-chan-wb (weathered basalt)	Spillway channel in the main *nalla* of Manhere and south of the village: 19°34.40'N 73°47.18'E	15x25 cm	Test#2:2.56x10^{-5} Test#2:2.56x10^{-5} Test#3.1.75x10^{-5} Test#4:1.45x10^{-5} Test#5:1.45x10^{-5}
Man-chan-m (murum surface)	See above	Lined 30X30 cm	Test#7.69x10^{-5}

Radon Levels In Akole Area

8A Radon In Soil Gas Of Akole Taluka : May 1995

Test site	Description and location	Sample Pipes	Radon level ($_p$Ci/L)
Radon-1 Manhere (May 3)	Paddy field south of the main *nalla*. Site of surface infiltration test Man-paddy and water source MW19. 10034.12'N73047.63'E and 719 m.	5 spaced at 10 m	Pipe#1:579 (east)weathered bedrock Pipe#2:538 Pipe#3:544 Pipe#4:671 Pipe#5:603 (West)
Radon-2 Manhere (APril 30) (*=May 15)	Paddy field south of the village in the main *nalla*. Site of water source MW 18. 19034.19'A 73047.36'E and 730 m.	5 spaced at 5 m	West hillside 582*Pipe#1:838 (east) 414* (on liner) Pipe#2:629 Pipe#3:657 Pipe#4:528 Pipe#5:560 (West)
Raddon-3 Manhere (May 5)	Paddy field northwest of the village in the main *nalla*. Ground feature (N450W) evident at the water source. 19034.88'N 73047.12'E and 764m.	3 spaced at 10 m and one on the ground feature to the southeast.	Pipe#1:422 (north) Pipe#2:465 (on liner) Pipe#3:561 (south) Pipe #4:330 (linear to SE) Pipe#4:330 (linear to SE) weathered bed rock
Radon-4 Titvi (May 8)	Step-sided valley northwest of the village. 19034.925'N 73048.54'E and 712-730 m.	3 spaced at 50m	Pipe#1:369 (north) hilltop Pipe#2:309 valley (on liner) weathered bedrock Pipe#3:533 (south) hilltop

8B Location Map Of Radon Tests



9A DAILY RAINFALL OF BHANDARDARA STATION (1994) IN MM

Date	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1						2	62	15	6.5			
2							8.5	83	70			
3							13	73.5	105			
4							6	13.5	10			
5						8	14.5	3.5	24			
6						8.5	11	2	72			
7							30.5	2	52			
8							46	22	81.5			
9							24	31	31.5			
10				10.5		25	47	14.5	28		12	
11							80	44	10			
12	50						74	37.5	1.5	4.5		
13				3		13.5	137	26.5				
14						15	214.5	11.5				
15						22.5	154	13.5				
16						114.5	75.5	13		9		
17						57.5	56.5	26	1.5			
18						20	81.5	52.5	6.5	2		
19						45	78	12.5	1			
20						0.5	145.5	48	3.5			
21								123.5	16.5			
22						5	75	12				
23						38	68.5	1.5				
24						67	85	10.5				
25						12	40.5	43.5				
26						21	60	43				
27						33.5	36.5	135.5				
28						20	40	96.5				
29						93.5	45	18				
30						10.5	40.5	47.5				
31								23.5	31			
Total	50	0	0	13.5	0	632.5	1997	1001	504.5	15.5	12	0

Total Annual Rainfall = 4225.5 mm

9B DAILY RAINFALL OF MANHERE STATION (1994) IN MM

Date	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1									4.25			
2									9.5			
3									11.35	11.2		
4									72.5			
5									39.45		10.5	
6						10.5			92.4		1	
7						0.5		0.5	28			
8								16.5	64.4			
9								30	45.25			
10						32.5		36	30			
11							74.5	48		24.53		
12							108.5	33		24.13		
13						3.6	81.5	34	0.8	12.35		
14						9	74.5	15	6.25			
15						16	108.5	11	0.8		12	
16						65	81.5	26.5	7.25			
17						24.5	46.5	32				
18						17.5	74.5	43.5	5.4	20		
19						40.5	35	11.5		13.3		
20						0.5	51	33.5		4.1		
21							120.5	30		14		
22							62.5	13.5				
23							73.5					
24							63	10.5		16.3		
25							48	19.5				
26						21	71.5	19.5				
27						33.5	23.5	18				
28						20	43	11.5				
29						93.5	73.5	11				
30						10.5		7				
31								3.2				
Total	0	0	0	0	0	398.7	1315	514.7	417.6	139.9	23.5	0

Total Annual Rainfall = 2809.37 mm

PUBLICATIONS AND FILMS ON RURAL DEVELOPMENT FROM BAIF

Watershed Development

Soil and Water Conservation Structures in Watershed Development Programmes	A reference manual by **B. K. Kakade** Pages 50, Price Rs. 100/- Available in English and Marathi

Forestry and Environment

Books & Proceedings of Workshops

Handbook of Wastelands Development	A practical guide for field technicians. Edited by **Dr. N. G. Hegde**. *Pages 180, Price Rs. 50*
Agroforestry : Selected Readings	Edited by **Dr. N. G. Hegde** and **V. D. Kelkar**. *Pages 98, Price Rs. 36*
Value Addition to Biogas Effluent Through Vermicomposting Using Earthworms	A research report by **G. G. Sohani, A. L. Joshi, V. C. Badve** and **P. S. Mukherji**. *Pages 40, Price Rs. 30*
The Greening of Wastelands	National Workshop on 'Utilisation of Wastelands for Bioenergy', held in April 1985 Edited by **Dr. N. G. Hegde** and **P. D. Abhyankar**.*Pages 204, Price Rs. 60*
Sustainable Environment Protection	National Workshop held in January 1998. Edited by **Dr. A.L. Joshi, S.E. Pawar, B.K.Kakade and Dr. A.S. Ghorpade.** *Pages 100, Price Rs. 90/-*
Promotion of Fodder and Fuelwood Trees	National Workshop on Research and Extension Needs for Promotion of Fodder and Fuelwood Trees' held in July 1988 Edited by **Dr. N. G. Hegde, L. L. Relwani** and **V. D. Kelkar**. *Pages 264, Rs. 85*
Multipurpose Tree Species for Small Farmers	National Workshop held in January 1991 Edited by **Dr. N. G. Hedge** and **Dr. J. N. Daniel**. *Pages 147, Price Rs. 50*
Promotion of Non-wood Forest Produce through Social Forestry	National Workshop held in March 1992 Edited by **Dr. N. G. Hegde** and **Dr. J. N. Daniel**. *Pages 257, Price Rs. 50*
Role of Women in Promotion of Multipurpose Tree Species	National Workshop held in March 1993 Edited by **Dr. N. G. Hegde** and **Dr. J. N. Daniel**. *Pages 76, Price Rs. 30*
Multipurpose Tree Species for Agroforestry in India	National Workshop held in April 1994 Edited by **Dr. N. G. Hegde** and **Dr. J. N. Daniel**. *Pages 137, Price Rs. 50*

Training Manuals

Nitrogen Fixing Trees	Available in English. Author : **Dr. J. N. Daniel**. *Page 16, Price Rs. 5*
Low cost technology for Afforestation on Wastelends	Available in English and Marathi Author : **N. G. Hegde**. *Pages 16, Price Rs. 5*
Nursery raising Techniques for Multipurpose Tree Species	Available in English. Author : **V. D. Kelkar.** *Pages 16, Price Rs. 5*
Agroforestry	Available in English. Author : **Dr. J. N. Daniel**. *Pages 16 Price Rs. 5*
Shaping Your Land	A training booklet by **G. G. Sohani**. Available in English Hindi, Marathi, Gujarati and Kannada. *Pages 10, Price Rs. 5*
Planting And Aftercare of Fruit Trees	A training booklet by **G. G. Sohani**. Available in English, Hindi, Marathi, Gujarati and Kannada. *Pages 10, Price Rs. 5*

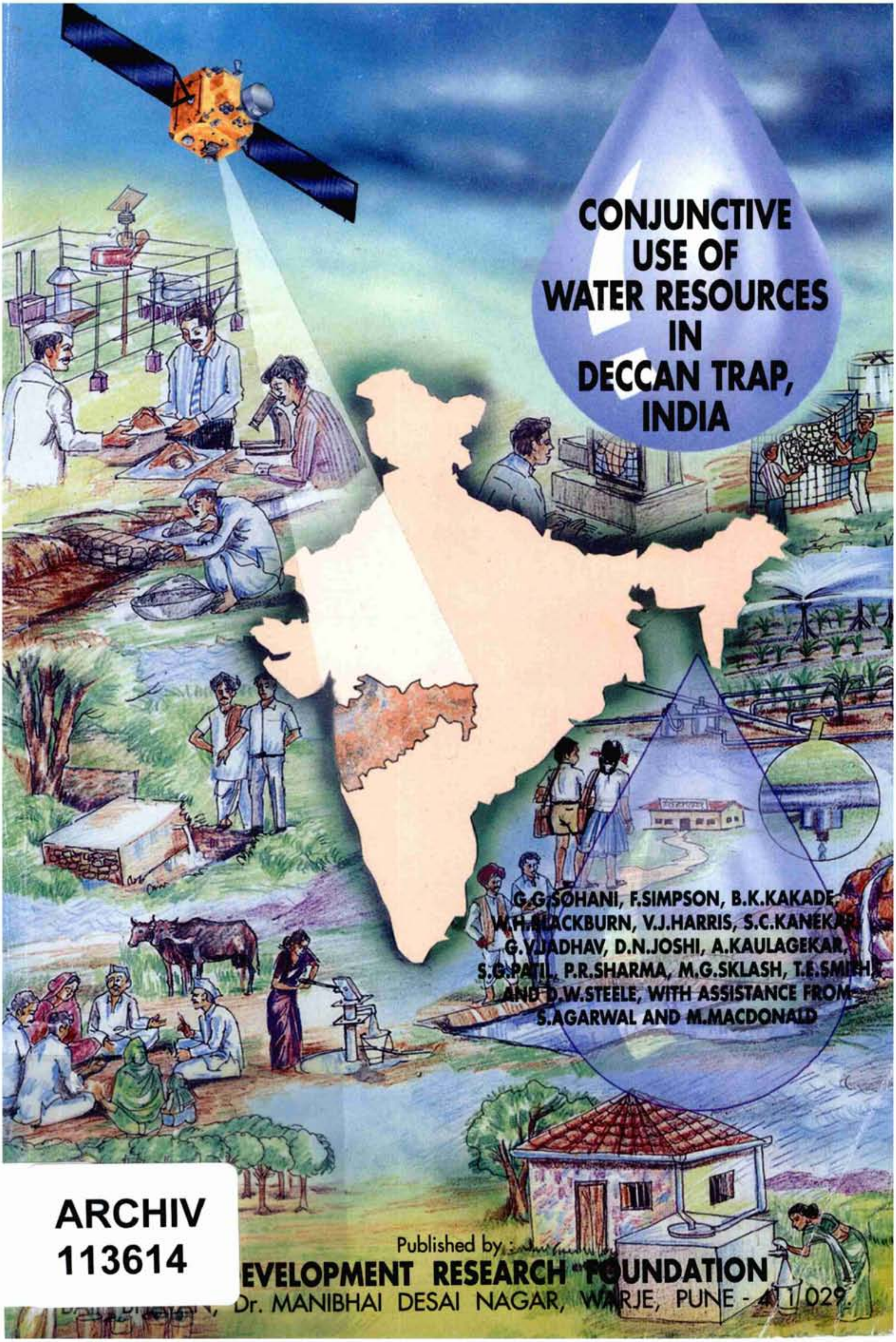
FILMS

Golden Earth (Sunahari Dharti)	A film on soil and water conservation. Duration : 22 minutes. Available in English, Hindi, and Marathi. 16 mm Rs. 9900 VHS Edition Rs. 600
The A Frame	A film on how to make an A Frame and use it effectively on the field. Duration : 14 minutes Available in English, Hindi and Marathi. 16 mm Rs. 6800 VHS Edition Rs. 600

◆◆◆◆

महाराष्ट्र शासन
आदिवासी विकास विभाग
सन्मान पत्र
महाराष्ट्र राज्यात
आदिवासी विकासाच्या क्षेत्रात
उल्लेखनीय कार्य केल्याबद्दल शासन
यांना
आदिवासी सेवा संस्था पुरस्कार
प्रदान करीत आहे.

BAIF Development Research Foundation
has been honoured by
'Tribal Service Organisation Award'
for the year 1996-97 by Government of Maharashtra.
The award has been given to BAIF
for outstanding tribal development work in Ahmednagar and Thane district of Maharashtra.
The project
'Conjunctive Use of Water Resources in Deccan Trap, India'
has contributed the work in
three villages of Akole taluka in Ahmednagar district.


CONJUNCTIVE
USE OF
WATER RESOURCES
IN
DECCAN TRAP,
INDIA
G.G.SOHANI, F.SIMPSON, B.K.KAKADE, W.H.BLACKBURN, V.J.HARRIS, S.C.KANEKAR, G.V.JADHAV, D.N.JOSHI, A.KAULAGEKAR, S.G.PATIL, P.R.SHARMA, M.G.SKLASH, T.E.SMITH, AND D.W.STEELE, WITH ASSISTANCE FROM S.AGARWAL AND M.MACDONALD
Published by :
EVELOPMENT RESEARCH FOUNDATION
Dr. MANIBHAI DESAI NAGAR, WARJE, PUNE - 411 029.

महाराष्ट्र शासन
आदिवासी विकास विभाग
सन्मान पत्र
महाराष्ट्र राज्यात
आदिवासी विकासाच्या क्षेत्रात
उल्लेखनीय कार्य केल्याबद्दल शासन
यांना
आदिवासी सेवा संस्था पुरस्कार
प्रदान करीत आहे.

BAIF Development Research Foundation
has been honoured by
'Tribal Service Organisation Award'
for the year 1996-97 by Government of Maharashtra.
The award has been given to BAIF
for outstanding tribal development work in Ahmednagar and Thane district of Maharashtra.
The project
'Conjunctive Use of Water Resources in Deccan Trap, India'
has contributed the work in
three villages of Akole taluka in Ahmednagar district.